UNIVERSIDADE DE LISBOA

FACULDADE DE MOTRICIDADE HUMANA

WELL-BEING BENEFITS OF GREEN EXERCISE IN HEALTHY ADULTS: SYSTEMATIC REVIEW AND META-ANALYSIS

Dissertação elaborada com vista à obtenção do Grau de Mestre em Exercício e Saúde

Orientador: Doutor Duarte Fernando da Rosa Belo Patronilho de Araújo

Júri:

Presidente: Doutor Pedro Jorge do Amaral de Melo Teixeira

Vogal: Doutor Duarte Fernando da Rosa Belo Patronilho de Araújo

Vogal: Doutor António João Labisa da Silva Palmeira

Vogal: Doutor Hugo Miguel Borges Sarmento

Henrique Manuel da Silva Brito

2018

Agradecimentos:

Em primeiro lugar, aos meus pais, pela educação que me proporcionaram, a qual me permitiu ser quem sou. Estou-vos eternamente grato.

Aos professores e colegas da Faculdade de Motricidade Humana, e da Faculdade de Ciências do Desporto e Educação Física da Universidade de Coimbra, cuja ajuda foi indispensável.

À Leila, por me acompanhar em todos os momentos, os melhores e os mais difíceis, da elaboração desta dissertação.

Abstract

Research shows that exercising in outdoor natural environments (green exercise) tends to promote higher well-being benefits than exercising in indoor environments; however, a meta-analysis of experimental studies is lacking. We conducted a systematic review and a meta-analysis comparing the mental well-being effects of exercising in green vs indoor environments. A total of 11 studies, from 2010 onwards, were collected. Qualitative analysis indicated greater psychological improvements of participants performing green exercise, comparing to those performing indoor exercise; however, there is a lack of methodological quality in most of the studies, and disparity in outcome measures. To aggregate more data from a broader time-span, a meta-analysis was performed in a pool of studies from the previously mentioned systematic review, plus nine other studies from a systematic review published by Coon et al., in 2011. Outcome measures included in the meta-analysis were related with affect and perceived exertion. Green exercise showed higher improvement in affect, and lower perceived exertion when compared to indoor exercise.

This systematic review and meta-analysis highlighted the need for more experimental studies on this topic. Results were consistent with previous evidence, and should be considered by health professionals and policy makers, to promote a more active lifestyle in increasingly sedentary populations of developed countries.

Keywords: Green Exercise, Indoor Exercise, Mental Health, Well-being, Systematic Review, Meta-analysis

Índice

Introduction

Recently, more attention has been given to researching the effects of exercising in different physical environments, particularly natural and artificial settings. Previous studies have consistently showed that the outdoor natural environment (e.g. green environments such as forests), may induce greater mental health and well-being benefits than the artificial indoor setting (e.g. gymnasiums). These benefits may be explained by specific features of natural green settings, like the presence of a slight breeze, water courses, predominance of green colors in the visible landscape, and even particular sounds. However, a previous literature review of this topic (Coon, et al., 2011) has found difficulties in assembling sufficient data to strengthen this statement, which means that the exact differences between exercising in outdoor natural, and indoor settings, have yet to be identified, relative to mental health and well-being changes.

The aim of this dissertation was to conduct a systematic review of experimental studies, on the effects of green exercise on mental health and well-being, and then, perform a meta-analysis on specific outcomes, to identify differences between green and indoor environments. Consequently, this dissertation includes two studies, one qualitative systematic review, conducted according to PRISMA guidelines, and one quantitative meta-analysis, performed with the adequate software on specific measures.

The "Bond" Between Man and Nature

The relationship between human beings and nature spans millions of years, and humans and other animals developed in contact with nature's resources, landscapes and biodiversity. This idea of connection and exchange was suggested by Wilson as the Theory of Biophilia (Wilson, 1984), which is defined as the innate attraction of human beings by nature and other living organisms, which can lead to health and well-being benefits. Historically, the presence of natural elements, such as trees, gardens, and green spaces, has been very important for human societies. For example, *Champ de Mars* in Paris, and Central Park in New York City, are some of the world's best-known urban green parks. However, lately this theory has been challenged and built upon by the Topophilia Hypothesis, reemerged from the work of Tuan (Tuan, 1974). Topophilia suggests that specific features of the evolutionary habitat are responsible for shaping our species and facilitating acquisition of skills and knowledge. So, it is possible that humans feel a connection with specific types of habitats, or locations, containing not just living organisms and vegetation, but also nonliving features such as stones and water. Tuan suggested that the sea-shore, as one of such possible habitats, allowed humans to hunt freely and safely, and promoted skill acquisition (Beery, Jonsson, & Elmberg, 2015).

Based on these ideas, an increasing number of studies show that the presence of natural elements (such as plants, trees, and views of natural landscapes) in indoor and outdoor environments, can improve cognitive functioning, physical and mental health, and well-being (Bergman, Jonides, & Kaplan, 2008; Dravigne, Waliczek, Lineberger, & Zajicek, 2008; Horiuchi, et al., 2014; Triquero-Mas, et al., 2015). These effects were also showed in a literature review by Bowler (Bowler, Knight, Pullin, & Buyung-Ali, 2010), who explored the benefits of different activities in natural and synthetic environments (including indoor, outdoor built, and outdoor natural spaces), and concluded that natural environments may have a greater positive impact on well-being than synthetic environments. Furthermore, and importantly for this thesis, having easy accesses to green spaces is associated with a higher level of physical activity (Astell-Burt, Feng, & Kolt, 2013; Astell-Burt, Feng, & Kolt, 2014).

Some of these studies are framed by Kaplan's Attention Restoration Theory (ART), which proposes that man-made, unattractive built environments impose use of forced voluntary attention. In this view, attention is a limited mental resource that can become depleted with excessive use of voluntary attention, causing mental tiredness. Contrastingly, natural green environments have regenerative characteristics that allow the use of a kind of involuntary attention, therefore avoiding mental fatigue and facilitating attention restoration (Kaplan & Kaplan, 1989; Kaplan S. , 1995). In a convergent theoretical approach, Ulrich's Stress Recovery Theory (SRT) suggests that pleasant natural environments can reduce stress, while synthetic environments prevent stress recovery. Thus, this regenerative influence of nature can promote positive emotional states and physiological adaptations (Ulrich, 1983; Ulrich, et al., 1991).

Green Exercise

Nowadays a greater importance is given to health prevention, contrary to conventional health care, and accordingly, it is well known that engaging in physical activity promotes not only benefits for physical health, but also benefits for mental health and increased well-being (Elkington, Cassar, Nelson, & Levinger, 2017; Shepherd, et al., 2015; Garber, et al., 2011).

Exercising in the outdoor natural setting has been labeled "Green exercise", which is defined by Pretty and colleagues as "adopting physical activities whilst at the same time being directly exposed to nature" (Pretty, Peacock, Sellens, & Griffin, 2005, p. 320). The concept arises from the hypothesis that potential synergistic effects might result from exercising in a natural setting, which could lead to greater physical and psychological health. A model of three potential relations between environment and physical activity could explain these effects. Such relations could be defined as "sub-additive" (less than total independent benefits), "additive" (equal to the sum of the parts), and "synergistic" (greater than the sum of the parts) (Shanahan, Franco, Lin, Gaston, & Fuller, 2016).

Increasing attention has been given to green exercise, showing it can promote numerous benefits, including reduced anxiety, improvements in self-esteem and mood (Rogerson, Brown, Sandercock, Wooller, & Barton, 2016; Mackay & Neill, 2010), greater feelings of happiness, affect, attention restoration, and overall mental well-being as opposed to indoor and built environments (Rogerson, Gladwell, Gallagher, & Barton, 2016; Rogerson & Barton, 2015; Calogiuri, Nordtug, & Weydahl, 2015; Krinski, et al., 2017; Shin, et al., 2013; Brown, Barton, Pretty, & Gladwell, 2014; Marselle, Irvine, & Warber, 2013), even in short bouts of green exercise. Furthermore, engaging in green exercise has shown greater potential for adherence to physical activity behaviors, when compared with indoor settings (Barton & Pretty, 2010; Coon, et al., 2011). Recent research suggests the presence of water, such as streams, lakes, and rivers, and the overall type of natural environment, have their impact but only in articulation with other features of the individual, the exercise routine, and the environment (Rogerson, Brown, Sandercock, Wooller, & Barton, 2016; White, Pahl, Ashbullby, Burton, & Depledge, 2015).

Placing Green Exercise in (Theoretical) Context: The Environment and the Individual as a Single System

Perception and action in the environment is a topic that has been studied and discussed by psychologists for decades. While behaviorists believe that information comes solely from the environment (thus, all behavior is a response to stimuli of the environment), cognitivists criticized behaviorism because behavior cannot simply be explained by reflexes (Stimulus-Response) (Anson, Elliott, & Davids, 2005). Cognitivists consider the world and the living being as separate dimensions, so, perception must be an active effort, and it is up to the living being to extract information from the environment through its sensory organs, and then create a representation of the environment (representational theory) (Costall, 1984). Despite there being differences in views, both these meta-theories (cognitivism and behaviorism) have points in common since they base their view of the environment as space ruled by physics (Gibson, 1979). Ecological dynamics, developed from Gibson's visual perception theory, has established itself as an alternative view to cognitivism and behaviorism. Through Gibson's work on Holt's stimulus-response formula, Gibson, as Costall states, "eventually came to realize that perception must be viewed as an act rather than as a response" (Costall, 1984, p. 110). Gibson suggested that space was not as a structureless container, but a layout of overlapping surfaces, objects, and events, and he also denied the cognitivist assumption that the individual is external to the environment. The ecological dynamics approach focuses on the interaction between the subject and his or her surrounding environment, which creates constraints that offer opportunities for perception and action (Gibson, 1979; Seifert & Davids, 2015). According to Araújo, in Gibson's ecological psychology, "the process of detecting information is carried out by a functional system distributed throughout an organism. Adjustments of peripheral organs, such as turning the eyes and head, play as significant a role in direct perception as the activity of the brain and the nervous system" (Araújo, 2009, p. 14). So, Gibson introduced the concept of affordances as a type of direct, effortless perception, that exist as a relationship between the physical properties of the environment and the individual. Affordances have been designated as possibilities, or calls for action, that the environment offers the individual, such as sitting on a surface, or reaching an object. As a relational characteristic of the individual and the environment, affordances depend on the individual's intentions and capabilities, for example, a chair may be too high, and not afford sitting to a crawling child, but might serve as a platform for an adult to reach a higher shelf in the kitchen.

Recently, the approach of ecological dynamics has been suggested as the most suitable to study experiences of exercise, and its psychological effects (Davids, Araújo, & Brymer, 2016). Researchers suggest that indoor exercise environments offer a very stable context, with controlled and invariable conditions, which offer a very limited landscape of affordances. On the other hand, natural exercise environments show varied characteristics, challenging and complex affordances, that attract the attention of the subject, promoting psychological and emotional behaviors, and adherence to physical activity (Rogerson, Brown, Sandercock, Wooller, & Barton, 2016; Yeh, Stone, Churchill, Brymer, & Davids, Designing Physical Activity Environments to Enhance Physical and Psychological Effects, 2016; Bjørgen, 2016). Thus, affordances, within the ecological dynamics perspective, may be a more fruitful alternative way to understand and apply the results of green exercise research (Withagen & Caljouw, 2015; Rietveld & Kiverstein, 2014; Davids, Araújo, & Brymer, 2016).

Exercising in natural environments can promote greater psychological benefits than exercising in synthetic, built environments. Perhaps the lack of features such as natural light, wind breeze, in addition to the predominant neutral colors, and air condensation, may limit potential higher benefits from exercising. To address similar questions, Thompson Coon and colleagues (2011) conducted a systematic review on the experimental studies on this topic, up to 2010. They showed that there is evidence for greater improvements in mental health and well-being outcomes for exercising in natural environments, comparing to exercising indoors, although studies also displayed considerable lack of methodological quality, and heterogeneity in outcome measures. For the preset theses, we aimed to 1) collect and discuss more recent research on the topic, and 2) perform a meta-analysis on the studies with enough quality.

Study 1. Systematic Review

Introduction

In a systematic review by Coon (Coon, et al., 2011), 11 experimental studies comparing the effects of exercising in outdoor natural (green) environments, and exercising indoors, on physical and mental well-being outcomes, were screened and analyzed. The authors concluded there were observable greater benefits of exercising in the natural environment. However, they also pointed to a limited number of published studies, and to the existence of variability in the outcome measures for similar psychological states. These criticisms made it impossible for them to be more convincing in their conclusions, as it happens if they conducted a meta-analysis. After 8 years we expected to find more studies and then analyze the state of the art of this topic.

The rationale for this study is the need to understand specific benefits (and causes of those benefits) of exercising in both the green and the built environments. The health and well-being benefits of exercising in Nature may be attributed to characteristics inherent to these environments such as sunlight, wind breeze, surrounding biodiversity, and more intense and complex affordances, which are supported by the theoretical frameworks of Ecological Dynamics, Attention Restoration Theory, and Stress Recovery Theory (Rogerson, Brown, Sandercock, Wooller, & Barton, 2016; Davids, Araújo, & Brymer, 2016; Ulrich, et al., 1991). The role of specific features in the environment is not well known, and may be the catalyst for promoting well-being benefits.

The aim of the present study was to conduct a systematic review according to PRISMA guidelines (The Prisma Group, Moher, Liberati, Tetzlaff, & Altman, 2009), of relevant experimental studies, published from 2010 onwards, about the effects of exercising in outdoor natural environments, as opposed to exercising in indoor environments, on mental health and well-being outcome measures. If additional studies and data can be collected from recent years, it may be possible to better determine the influence these two exercise environments may have for mental health and well-being.

Method

Eligibility criteria.

The eligibility criteria for this systematic review only included studies that carried out a specific exercise intervention (in groups or individuals alone), in two different environments, one outdoor green setting, and an indoor setting with no natural elements. Also, simulations of natural environments in laboratory were eligible. In terms of study duration, short-term studies (e.g. one single episode of exercise), and long-term studies (e.g. structured training programs) were included; and considering study design, both parallel group, and crossover designs were eligible. Only adult samples were selected, randomized or not. Finally, the measures of interest, i.e., the outcome (dependent) variables, were well-being states, including cognitive, and emotion-based outcomes. The selected studies were published from 2010 onwards, i.e., after Coon et al.'s (2011) systematic review.

Search and study selection.

The search was conducted in the Web of Science™ databases (Web of Science™ Main Collection, Current Contents Connect, Derwent Innovations Index, Korean paper database, Medline, Russian Science Citation Index, SciELO Citation Index). During the search process, it was noted that topic-related indexing categories "Sports Sciences", "Public, Environmental & Occupational Health", and "Behavioral Sciences", were too extensive for a restricted search to the subject of this study, and therefore they were not used as a search filter. Also, there was no helpful MeSH terms to support study exploration.

The keyword search timeframe spans from 2010 to February 2017, and was based on the strategy reported in a systematic review by Coon (Coon, et al., 2011), with additional keywords found in relevant scientific literature. Consequently, studies would be considered if they included (1) one specific exercise intervention in outdoor natural, and indoor environment, (2) outcome measures of mental health and well-being, and (3) healthy adult samples. Thus, the keywords used in the search would represent four aspects: the green environment, the indoor environment, exercising, and measures of mental states and well-being (table 1). During the screening stage of the search, two researchers read the titles, abstracts, and full texts of eligible studies, and applied the eligibility criteria, and if there was no consensus among the reviewers, a third researcher would be contacted. Reference lists of identified studies were later screened to identify more relevant studies.

Table 1. Web of Science™ Search Strategy and Keywords for Experimental Studies on Green Exercise

Step	Keywords
1	TS="green exercise"
2	TS=”green gym*”
3	TI=((“outdoor*” OR “outside”) AND (“exercis*” OR “physical activity” OR “walk*” OR “recreat*” OR “run*” OR “play*” OR training OR workout))
4	TI=((greenspace* OR "green space*" OR rural OR green NOT tea NOT coffee) AND (exercis* OR "physical activity" OR walk* OR recreat* OR run* OR play* OR training OR workout))
5	TI=((“natural environment*” OR natur* OR "natural landscape*") AND (“exercis*” OR “physical activity” OR “walk*” OR “recreat*” OR run* OR “play*” OR training OR workout))
6	TI=((“park*" NOT “Parkinson*”) AND (“exercis*” OR “physical activity” OR “walk*” OR “recreat*” OR run* OR “play*” OR training OR workout))
7	TI=((trail OR forest* OR woodland* OR woods) AND (“exercis*” OR “physical activity” OR “walk*” OR

Step	Keywords
	“recreat*” OR “run*” OR “play*” OR training OR workout))
8	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7
9	TS=(indoor* OR inside* OR laboratory OR "sports cent*" OR gym* OR "fitness cent*" OR "sport* facilit*")
10	TS=(affect OR affective OR affects OR “self esteem” OR self-esteem OR selfesteem OR mood OR “well being” OR well-being OR wellbeing OR depression OR anxiety OR psychological OR mood OR mental OR emotion* OR cognit*)
11	8 AND 9 AND 10 = 82

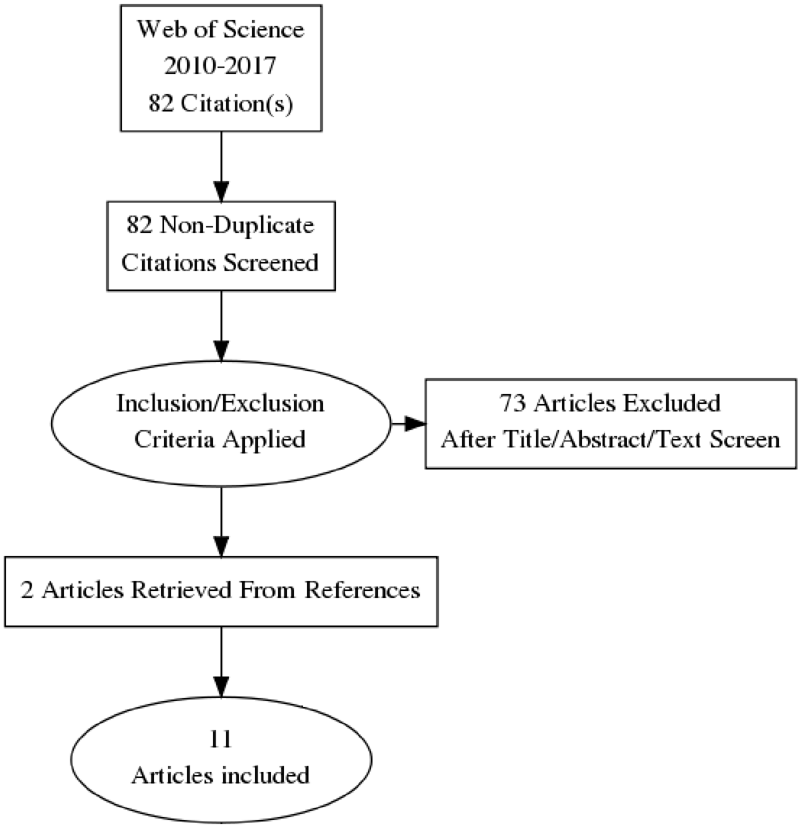
Note: TS = Topic search; TI = Title search

Results

Included studies.

82 records were found in the Web of Science^{TM} databases. After reading titles and abstracts, 68 records were excluded, with the following causes of rejection: topic not related to research question (n = 41), study design or method not suitable (n = 23), and sample not suitable (n = 4). The remaining 14 studies’ full text was screened, and five additional studies were excluded because full-text was not available (n = 2), and because study design / method was not suitable (n = 3). In total, nine studies were selected for analysis and after screening their reference sections two more studies were identified. Therefore, a total of 11 studies were selected for in-depth reading and analysis (Figure 1).

Figure 1. Flowchart of Database Systematic Search for Experimental Studies on Green Exercise



Methodological design of the studies.

All identified studies were experimental trials, including one study that was part of a report (Calogiuri, et al., 2015), and another one, which was part of a dissertation (Williams, 2011). Moreover, one study did not perform randomization on subjects (Yeh, Stone, Churchill, Brymer, & Davids, Designing Physical Activity Environments to Enhance Physical and Psychological Effects, 2016).

Samples

A total of 365 participants were counted, and the individual studies' samples ranged from 5 to 139 subjects; pooled mean age was 32.57, and most participants were women (81.92%).

Samples represented very diverse populations, including menopausal women, office employees, regular exercise practitioners and runners, students, and young adult women. Furthermore, physical activity level was varied within and between samples in studies, including sedentary people, recreational or regular exercise practitioners, and athletes (Table 2).

Duration and Exercise Type, Volume, and Intensity

Four articles implemented a long-term training program to study cumulative effects of exercising in outdoor natural and indoor environments (Calogiuri, et al., 2015; Calogiuri, et al., 2014; Calogiuri, Nordtug, & Weydahl, 2015; Lacharité-Lemioux, Brunelle, & Dionne, 2014), and the remaining seven articles implement an isolated episode of exercise also in the same types of settings (Shin, et al., 2013; Turner & Stevinson, 2017; Rogerson, Gladwell, Gallagher, & Barton, 2016; Yeh, Stone, Churchill, Brymer, & Davids, Designing Physical Activity Environments to Enhance Physical and Psychological Effects, 2016; Williams, 2011; Rogerson & Barton, 2015; White, Pahl, Ashbullby, Burton, & Depledge, 2015). The exercise routines performed in interventions are varied by type of training, volume and intensity. The types of exercise used in these studies include walking, running, cycling (or cycle ergometer), and combined aerobic and resistance training (Table 2).

Table 2. Methodological and Sample Characteristics of the Studies Included in the Systematic Review

Study, year	Study design	Duration	Intervention	Sample	Physical Activity level
Lacharité-Lemioux, 2014	Randomized parallel arms	12 weeks[a]	Aerobic and resistance training	23 post-menopausal women	Sedentary
Turner, 2017	Randomized counterbalanced crossover	At least 24h apart between conditions[b]	6 km run	22 runners (14 male, 8 female)	Recreational / Competitive

Shin, 2013	Randomized parallel arms	One occasion per group[b]	90-minute walk	139 female college students	Sedentary / Recreational
Rogerson, 2016	Randomized counterbalanced crossover	Average 9.4 days between conditions[b]	15-minute cycloergometer	24 (19 female, 5 male)	n.r.
Calogiuri, 2014	Randomized counterbalanced crossover	10 weeks[a]	Cycling and resistance training	14 office employees (7 female, 7 male)	Sedentary / Recreational
Yeh, 2016	Counterbalanced crossover	At least 7 days between conditions[b]	20-minute treadmill run	30 (18 male, 12 female)	Recreational
Williams, 2011	Randomized counterbalanced crossover	2 weeks[b]	30-minute run	26 young adult women	Sedentary / Recreational
White, 2015	Randomized counterbalanced crossover	Trials took place approximately a week apart[b]	15-minute cycloergometer	37 post-menopausal women	Sedentary / Recreational
Calogiuri, 2015	Randomized parallel arms	10 weeks[a]	Cycling and resistance training	19 office employees (11 female, 8 male)	n.r.
Rogerson, 2015	Randomized counterbalanced crossover	13 days average time between conditions[b]	15-minute treadmill run	12 (6 female, 6 male)	n.r.
Calogiuri, 2015	Semi-randomized parallel Groups	10 weeks[a]	Cycling and resistance training	19 office employees (11 female, 8 male)	Sedentary / Recreational

Note: n.r. = not reported; [a] = Long-term study implementing training programs; [b] = Short-term study implementing one occasion of exercise in both settings

Exercise Environments

The outdoor green environment used for interventions in selected studies mostly included areas such as natural parks, and large areas of maintained grassland partly interspersed with trees, sometimes with streams in view and a few built elements such as houses, streetlights, and benches (Lacharité-Lemioux, Brunelle, & Dionne, 2014; Williams, 2011; Calogiuri, Nordtug, & Weydahl, 2015; Calogiuri, et al., 2015). Also noted were large woodland or forest areas (Turner & Stevinson, 2017; Shin, et al., 2013; Calogiuri, et al., 2014; Rogerson & Barton, 2015), a botanical garden (Yeh, Stone, Churchill, Brymer, & Davids, Designing Physical Activity

Environments to Enhance Physical and Psychological Effects, 2016), and a rural green field with cattle nearby and a small wood (White, Pahl, Ashbullby, Burton, & Depledge, 2015). Moreover, three articles carried out a simulation of the green environment in the laboratory, by placing a screen where subjects watch a video or image of outdoor natural environments (Yeh, Stone, Churchill, Brymer, & Davids, Designing Physical Activity Environments to Enhance Physical and Psychological Effects, 2016; White, Pahl, Ashbullby, Burton, & Depledge, 2015; Rogerson & Barton, 2015).

Regarding the indoor environments, usually it consisted of a gymnasium (Turner & Stevinson, 2017; Yeh, Stone, Churchill, Brymer, & Davids, Designing Physical Activity Environments to Enhance Physical and Psychological Effects, 2016; Calogiuri, Nordtug, & Weydahl, 2015), a sports facility (Williams, 2011), a large room (Lacharité-Lemioux, Brunelle, & Dionne, 2014; Turner & Stevinson, 2017; Calogiuri, et al., 2014; Calogiuri, et al., 2015), or a laboratory (Rogerson, Gladwell, Gallagher, & Barton, 2016; White, Pahl, Ashbullby, Burton, & Depledge, 2015) (Table 3).

Table 3. Description of the Settings Addressed in the Studies Included in the Systematic Review

Study, year	Green setting	Indoor setting
Lacharité-Lemioux, 2014	Natural park beside a body of water, with paths lined with large trees, a river, and rich biodiversity.	Large meeting room with carpeted floor and many windows with view to a parking lot.
Turner, 2017	Large woodland area, with trails lined with trees and bushes.	Large fitness suite.
Shin, 2013	Forest largely undisturbed by artificial development with a trail endowed with old-growth, broad-leaved evergreen trees.	Gymnasium.
Rogerson, 2016	Large area with maintained grassland, lined and Partly interspersed with trees.	Laboratory setting, whereby participants' view was of a white Painted brick wall.

Study, year	Green setting	Indoor setting
Calogiuri, 2014	Track in a forest area, and a grass-yard.	Room with a large line of windows covered by white curtains.
Yeh, 2016	Indoor setting viewing a nature video of running in a path through a garden, recorded at the Sheffield Botanical Gardens.	Gymnasium.
Williams, 2011	Paved path lined with large trees, grass, and a small stream, around a well-maintained golf course and basketball and volleyball courts. Trees and vegetation shield the path from nearby roads, and the sounds of the traffic were complemented by chirping birds.	Indoor track with railings on the inner border and surrounded by cardiovascular equipment and windows on two of the walls. The windows provide views of a busy street, houses, a softball field, and trees.
White, 2015	Indoor setting viewing a video featuring three scenes of fields with sheep, hedgerows and a small wood.	Indoor laboratory with a blank wall.
Calogiuri, 2015	Area with trees and grass, and few built elements such as houses, streetlights, and benches.	Gymnasium with mirrors covering wall, and windows covered by white curtains.
Rogerson, 2015	Indoor setting viewing a video with scenes extracted from “Evening Run through Endless Forest”.	Room with a blank white screen.
Calogiuri, 2015	Patch surrounded by relatively small trees, and area surrounded by high bushes facing a forest.	Room with a large line of windows covered by white curtains. Yellowish walls, colorful mats and wooden complements, and a large mirror covering wall.

Outcomes

The most frequent measures used are perceived states of mood, affect, or feelings, where the most common questionnaire was the Feeling Scale (Hardy & Rejeski, 1989). There were also regular use of measures of arousal / activation, being the most common the Felt Arousal Scale (Svebak & Murgatroyd, 1985), as well as measures of subjective perception of exertion, namely the Rating of Perceived Exertion (Borg, 1990). Cognitive outcomes of attention and memory were found in only two studies. Self-esteem, depression, anxiety, vitality, and happiness were rarely measured (Table 5).

Risk of Bias

The assessment of quality of studies was based on the method described by Coon and colleagues (Coon, et al., 2011). Few authors calculated the power of the sample size in their studies, and in most cases, there were no explicit description of eligibility criteria. Additionally, only one study described concealment of exercise setting to participants, and the existence blindfolded evaluators (Lacharité-Lemioux, Brunelle, & Dionne, 2014). Baseline characteristics of samples were similar in all studies. Interventions were in general clearly described, and all measuring instruments, scales, and surveys were valid. Finally, results were reported with adequate statistical analysis in all studies, and conclusions and discussions were generally supported by the results. However, results of the studies cannot be generalized, given the low representativeness of samples (Table 4).

Table 4. Quality Assessment of the Studies Included in the Systematic Review

Quality Indicator	Lacharité-Lemioux, 2014	Turner, 2017	Shin, 2013	Rogerson, 2016	Calogiuri, 2014	Yeh, 2016	Williams, 2011	White, 2015	Calogiuri, 2015	Rogerson, 2015	Calogiuri, 2015
N calculation	Partial	Yes	No	No	Vague	No	Yes	No	Yes	No	No
Explicit eligibility criteria	Yes	Partial	Partial	Yes	Partial	Partial	Yes	Partial	Partial	Partial	Yes
Adequate randomization	Yes	Yes	Partial	Partial	Partial	Vague	Yes	Partial	Partial	Partial	Partial
Allocation concealment	Yes	Vague	Vague	Vague	Vague	Vague	Partial	Vague	Vague	Vague	Vague
Outcome assessor blinding	yes	Vague	Vague	Vague	Vague	Vague	Vague	No	Vague	Vague	Vague
Groups similar at baseline	Yes	Vague	Yes	Vague	Yes	Vague	Vague	Vague	Yes	Yes	Yes
All outcomes reported	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
All participants accouted for	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clear description of intervention	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Outcome measures valid and objective	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
All outcomes reported	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Yes = clearly described in study; Partial = reference to procedure without detail; Vague = no reference to procedure; No = non-realization of procedure reported in text

Summary of Results in the experimental Studies.

Long-term Studies

In the four long-term studies, exercising in the green environment showed significantly greater positive feelings and affect (Calogiuri, et al., 2015; Calogiuri, et al., 2014; Lacharité-Lemioux, Brunelle, & Dionne, 2014) greater perceived restoration (Calogiuri, et al., 2015; Calogiuri, et al., 2014; Calogiuri, Nordtug, & Weydahl, 2015), and decreased symptoms of depression (Lacharité-Lemioux, Brunelle, & Dionne, 2014) than exercising in the indoor environment. In addition, participants showed more enjoyment when exercising in the green environment (Calogiuri, et al., 2015; Calogiuri, Nordtug, & Weydahl, 2015) and showed greater adherence to regular physical activity (Lacharité-Lemioux, Brunelle, & Dionne, 2014). As for physiological measurements, the green environment group showed lower diastolic blood pressure, and smaller increases in blood cortisol during exercise (Calogiuri, et al., 2014). Nonetheless, between studies there was no observable consistent effect of similar instruments measuring emotion, mood, or affect, across these studies, although beneficial changes were usually greater for exercising in the green environment (Table 5).

Short-term Studies

In the seven short-term studies, exercising in the green environment showed significantly greater happiness (Shin, et al., 2013), increased attention (Rogerson & Barton, 2015), lesser feelings of distress, and greater restoration. In some cases, subjects also reported greater pleasantness of the natural setting over the indoor setting (Williams, 2011; White, Pahl, Ashbullby, Burton, & Depledge, 2015). On the other hand, exercising in the indoor environment showed decreased levels of directed attention in some studies (Rogerson, Gladwell, Gallagher, &

Barton, 2016), decreased positive engagement, and decreased tranquility (Lacharité-Lemioux, Brunelle, & Dionne, 2014).

Although some significant improvements in mental health and well-being outcomes were found, these improvements are not consistent across all studies. A considerable amount of studies found no significant differences for environment in measures of mood and affect (Rogerson, Gladwell, Gallagher, & Barton, 2016; Turner & Stevinson, 2017; Yeh, Stone, Churchill, Brymer, & Davids, Designing Physical Activity Environments to Enhance Physical and Psychological Effects, 2016; Williams, 2011), arousal (Lacharité-Lemioux, Brunelle, & Dionne, 2014; Turner & Stevinson, 2017; Rogerson, Gladwell, Gallagher, & Barton, 2016; Williams, 2011; White, Pahl, Ashbullby, Burton, & Depledge, 2015), perceived physical exertion (Lacharité-Lemioux, Brunelle, & Dionne, 2014; Turner & Stevinson, 2017; Rogerson, Gladwell, Gallagher, & Barton, 2016; White, Pahl, Ashbullby, Burton, & Depledge, 2015; Rogerson & Barton, 2015; Calogiuri, et al., 2015), subjective vitality (Turner & Stevinson, 2017), self-esteem, anxiety (Shin, et al., 2013), enjoyment (Rogerson, Gladwell, Gallagher, & Barton, 2016), and no differences in time perception (White, Pahl, Ashbullby, Burton, & Depledge, 2015). In fact, one study showed an increase in perceived exertion for exercising in the green environment (Williams, 2011) (Table 5).

Table 5. Results of the Included Studies and Description of Outcome Measures Used

Study	Measures	Indoor Mean ± SE	Green Mean ± SE	Comment
Lacharité-Lemioux, 2014	***Feeling Scale***[a]			
	Total pre	3.15 ± n.r.	3.12 ± n.r.	No significant effects
	Total post	3.3 ± n.r.	3.48 ± n.r.	
	Felt Arousal Scale[b]			
	Total pre	3.72 ± n.r.	3.69 ± n.r.	No significant effects
	Total post	4.52 ± n.r.	4.14 ± n.r.	
	Rating of Perceived Exertion[c]			
	Total post	14.12 ± n.r.	13.65 ± n.r.	No significant effects
	Exercise-induced Feeling Inventory[d]			
	Positive Engagement	n.r.	n.r.	Significant decrease for indoor (p = 0.025)
	Tranquility	n.r.	n.r.	Significant decrease for indoor (p = 0.029) and significant increase for green (p = 0.037)
	Revitalization	n.r.	n.r.	No significant effects
	Physical Exhaustion	n.r.	n.r.	No significant effects
	Adherence	91%	97%	Significantly greater for green (p = 0.007)
	Physical Activity Scale for the Elderly[e]			
		n.r.	n.r.	Significant increase for green (p = 0.044)
	Beck Depression Inventory[f]			
		n.r.	n.r.	Significant decrease for green (p = 0.035)
Turner, 2017	***Feeling Scale***[a]			
	pre	2,41 ± 1,62	2,45 ± 1,14	No significant effects
	mid	2,5 ± 1,65	1,86 ± 1,25	
	end	1,41 ± 2,99	1,59 ± 2,82	
	10 min post	3 ± 1,45	3,5 ± 1,6	
	Felt Arousal Scale[b]			
	pre	2,18 ± 1,05	2,09 ± 0,92	No significant effects
	mid	3,41 ± 0,96	3,5 ± 1,6	
	end	4,59 ± 1,14	4,77 ± 1,23	
	10 min post	2,73 ± 1,2	3 ± 1,45	
	Rating of Perceived Exertion[c]			
	pre	7,32 ± 1,91	7,18 ± 1,68	No significant effects
	mid	11,95 ± 2,08	12,95 ± 1,53	
	end	17,68 ± 1,91	17,36 ± 1,92	
	10 min post	8,68 ± 1,94	8,32 ± 1,99	
	Subjective vitality[g]			
		n.r.	n.r.	No significant effects
Shin, 2013	***State-trait Anxiety Inventory***[h]			
	Athletic group			
	Pre-walk	35.1 ± 6.9	36.3 ± 9.3	No significant effects
	Post-walk	36.8 ± 7.7	34.6 ± 8.1	
	Meditative group			
	Pre-walk	41.0 ± 9.6	43.1 ± 8.1	
	Post-walk	30.6 ± 7.0	29.2 ± 4.3	
	Rosenberg self-esteem scale[i]			
	Athletic group			
	Pre-walk	31.9 ± 3.1	31.2 ± 4.6	
	Post-walk	32.6 ± 3.2	32.1 ± 4.1	No significant effects
	Meditative group			

	Pre-walk	28.8 ± 6.1	28.4 ± 4.6	
	Post-walk	32.5 ± 4.1	33.7 ± 3.5	
	Happiness Index for Koreans[j]			
	Athletic group			
	Satisfaction Pre	17.1 ± 2.9	15.6 ± 3.5	
	Satisfaction post	17.3 ± 2.4	16.6 ± 3.0	
	Positive emotion Pre	17.0 ± 2.8	15.4 ± 3.9	
	Positive emotion post	14.8 ± 3.5	16.2 ± 3.1	Significant increase for green ($p < 0.05$)
	Negative emotion Pre	6.3 ± 2.8	6.0 ± 3.3	
	Negative emotion post	8.5 ± 4.4	6.9 ± 3.5	
	Happiness Index Pre	27.8 ± 6.9	25.0 ± 8.9	
	Happiness Index post	23.6 ± 7.4	25.9 ± 7.1	
	Meditative group			
	Satisfaction Pre	14.3 ± 3.0	14.1 ± 3.2	
	Satisfaction post	16.6 ± 2.9	18.6 ± 2.6	
	Positive emotion Pre	13.2 ± 4.0	13.1 ± 3.5	
	Positive emotion post	16.5 ± 3.2	18.5 ± 2.5	Significant increase for green ($p < 0.01$)
	Negative emotion Pre	6.1 ± 3.1	8.9 ± 4.1	
	Negative emotion post	4.5 ± 2.4	5.3 ± 2.8	
	Happiness Index Pre	21.4 ± 7.3	18.4 ± 8.6	
	Happiness Index post	28.7 ± 6.6	31.8 ± 5.9	
	Profile of Mood States[k]			
	Total Mood Disturbance pre	145.9 ± 15.1	148.8 ± 20.6	
Rogerson, 2016	Total Mood Disturbance post	142.2 ± 14.0	145.5 ± 16.3	No significant effects
	Enjoyment of exercise session[l]			
	Post exercise	64.2 ± 23.4	65.9 ± 23.5	No significant effects
	Intention for future exercise behaviour[m]			
	Post exercise	69.7 ± 25.4	68.3 ± 22	No significant effects
	Rating of Perceived Exertion[c]			
	at 7:30 min	12.2 ± 2.5	11.9 ± 2.5	No significant effects
	at 14:00 min	13.5 ± 2.2	12.9 ± 2.2	
	Directed attention[n]			
	Pre exercise	3.5 ± 1.4	3.2 ± 1.7	Significant decrease for indoor ($p < 0.05$)
	Post exercise	3.0 ± 1.6	3.5 ± 1.7	
	Perceived Restorativeness Scale[o]			
	Fascination	1.90 ± 0.42	6.54 ± 0.42	Significant increase for *green* ($p < 0.01$)
Calogiuri, 2014	Being Away	4.82 ± 0.40	7.75 ± 0.40	Significant increase for *green* ($p \leq 0.01$)
	Physical Activity Affect Scale[p]			
	Positive affect	2.79 ± 0.10	3.50 ± 0.11	Marginal increase for *green* ($p = 0.06$)
	Tranquility	3.41 ± 0.13	3.42 ± 0.13	No significant effects
	Positive and Negative Affect Scale[q]			
Yeh, 2016	Positive Pre	24.3 ± 8.4	26.8 ± 8.1	No significant effects
	Positive Post	28.9 ± 7.3	28.2 ± 7.3	
	Negative pre	11.2 ± 2.2	12.5 ± 4.4	No significant effects
	Negative post	11.7 ± 1.7	11.6 ± 1.6	
	Feeling Scale[a]			
	Total	3.19 ± 1.45	3.56 ± 1.00	No significant effects
Williams, 2011	***Felt Arousal Scale***[b]			
	Total	4.12 ± 1.09	4.23 ± 1.03	No significant effects
	Activation-deactivation Adjective Checklist[r]			
	Energy pre	10.04 ± 3.65	10.15 ± 3.40	No significant effects
	Energy post	12.15 ± 3.41	12.88 ± 3.86	
	Calmness pre	13.04 ± 4.07	13.85 ± 4.07	No significant effects
	Calmness post	13.04 ± 3.41	12.96 ± 3.29	

	Tiredness pre	11.58 ± 4.36	11.54 ± 4.08	No significant effects
	Tiredness post	9.73 ± 3.75	8.42 ± 4.06	
	Tension pre	6.85 ± 2.59	6.69 ± 2.19	No significant effects
	Tension post	6.65 ± 2.33	6.38 ± 1.33	
	Rating of Perceived Exertion[c]			
	10 min	9.73 ± 2.01	10.73 ± 1.91	Significant increase for green ($p < 0.001$)
	20 min	10.50 ± 1.90	11.27 ± 1.82	
	30 min	10.69 ± 1.72	11.50 ± 1.84	
	Total	10.31 ± 1.88	11.17 ± 1.86	
	Attentional Focus Questionnaire[s]			
	Association	42.85 ± 11.37	41.31 ± 11.66	No significant effects
	Dissociation	36.23 ± 8.65	38.54 ± 9.13	No significant effects
	Distress	10.35 ± 4.94	1.30 ± 0.40	Significantly lesser for *green* ($p < 0.001$)
	Perceived restorativeness scale[o]			
		36.15 ± 15.68	38.23 ± 13.58	Significantly greater for *green* ($p = 0.005$)
	Evaluation of Exercise Setting[t]			
	Pleasant	6.54 ± 2.34	8.85 ± 1.38	Significantly greater for *green* ($p < 0.001$)
	Comfortable	7.27 ± 2.27	8.73 ± 1.22	Significantly greater for *green* ($p = 0.005$)
	Refreshing	6.00 ± 2.97	9.08 ± 1.20	Significantly greater for *green* ($p < 0.001$)
	Enjoyable	6.77 ± 2.37	8.81 ± 1.47	Significantly greater for *green* ($p = 0.001$)
	How much do you like exercising in this setting?			
		7.50 ± 2.32	9.23 ± 0.95	Significantly greater for *green* ($p = 0.001$)
	Which setting was the most pleasant?			
		8%	92%	Significantly greater for green ($p < 0.001$)
	Which setting was the most comfortable?			
		42%	58%	No significant effects
	Which setting was the most refreshing?			
		0	100%	Significantly greater for green ($p < 0.001$)
	Which setting was the most enjoyable?			
		8%	92%	Significantly greater for green ($p < 0.001$)
	Which setting most positively impacted your performance?			
		27%	73%	Significantly greater for green ($p < 0.05$)
	Which setting did you prefer?			
		15%	85%	Significantly greater for green ($p < 0.001$)
	If you were asked to choose between these two settings for an exercise session in the future, which one would you choose?			
		23%	77%	Significantly greater for green ($p < 0.01$)
White, 2015	***Feeling Scale***[a]			
	Pre	3.27 ± 1.46	2.61 ± 1.85	Significant increase for *green* ($p < 0.001$)
	5 min	2.58 ± 1.75	3.24 ± 1.19	
	10 min	2.68 ± 1.56	3.32 ± 1.16	
	15 min	2.75 ± 1.56	3.36 ± 1.46	No significant effects
	Post (5 min)	3.64 ±1.18	3.78 ± 0.92	
	Felt Arousal Scale[b]			
	Pre	2.84 ± 1.07	3.05 ± 1.08	
	5 min	2.50 ± 0.93	2.68 ± 1.06	
	10 min	2.32 ± 0.92	2.57 ± 1.21	No significant effects
	15 min	2.42 ± 1.16	2.53 ± 1.30	
	Post (5 min)	2.51 ± 1.17	2.54 ± 0.99	
	Time perception[u]			
	5 min	5.42 ± 1.73	5.61 ± 2.93	
	10 min	10.95 ± 2.32	10.97 ± 3.44	No significant effects
	15 min	17.22 ± 5.39	16.81 ± 5.30	

	Mean during	11.12 ± 2.85	11.05 ± 3.47	
	Rating of Perceived Exertion[c]			
	5 min	11.62 ± 1.48	11.57 ± 1.59	
	10 min	11.92 ± 1.67	12.22 ± 1.97	No significant effects
	15 min	12.28 ± 1.70	12.42 ± 1.63	
	Evaluation[t]			
	Enjoyed	3.18 ± 1.44	4.49 ± 1.37	Significantly greater for green (p < 0.001)
	Feel better	3.49 ± 1.59	4.62 ± 1.42	Significantly greater for green (p = 0.006)
	Repeat	3.76 ± 1.40	4.81 ± 1.43	Significantly greater for green (p < 0.001)
Calogiuri, 2015	***Perceived Restorativeness Scale***[o]			
	Assessment Fascination	1.80 ± 1.80	3.80 ± 2.70	Significantly greater for *green* (p = 0.04)
	Assessment Being Away	3.50 ± 4.3	6.50 ± 4.50	
	Intervention Fascination	1.90 ± 0.42	6.54 ± 0.42	Significantly greater for *green* (p < 0.001)
	Intervention Being away	4.82 ± 0.40	7.75 ± 0.40	
	Rating of Perceived Exertion[c]			
	Assessment study	12.0 ± 3	8.0 ± 3	Significantly lesser for *green* (p = 0.04)
	Intervention Study	n.r.	n.r.	No significant effects
	Intention to exercise in future[m]			
		1.11 ± 0.46	2.90 ± 0.38	Significantly greater for *green* (p < 0.01)
Rogerson, 2015	***Backwards Digit Span Task***[v]			
		n.r.	n.r.	Significantly greater for *green* (p = 0.007)
	Rating of Perceived Exertion[c]			
	Exercise 1 (4:30 mins)	n.r.	n.r.	
	Exercise 1 (9:30 mins)	n.r.	n.r.	
	Exercise 1 (14:30 mins)	n.r.	n.r.	No significant effects
	Exercise 2 (2 mins)	n.r.	n.r.	
	Exercise 2 (4 mins)	n.r.	n.r.	
Calogiuri, 2015	***Perceived Restorativeness Scale***[o]			
	Fascination	n.r.	n.r.	Significantly greater for *green* (p < 0.001)
	Being away	n.r.	n.r.	
	Connectedness to Nature Scale[x]			
		n.r.	n.r.	No significant effects
	Physical Activity Affect Scale[p]			
	Positive Affect	n.r.	n.r.	Significantly greater for *green* (p < 0.001)
	Negative Affect	n.r.	n.r.	
	Fatigue	n.r.	n.r.	No significant effects
	Tranquility	n.r.	n.r.	
	Rating of Perceived Exertion[c]			
	Biking (workout)	n.r.	n.r.	
	Biking (at completion)	n.r.	n.r.	No significant effects
	Strength (at completion)	n.r.	n.r.	
	Enjoyment[l]			
	Biking	n.r.	n.r.	Significantly greater for *green* (p < 0.001)
	Rubber-bands	n.r.	n.r.	Significantly greater for *green* (p = 0.04)

Note: n.r. = mean value not reported in study; [a]Feeling scale scores range from minus 5 (very bad) to 5 (very good); [b]Felt Arousal Scale scores range from 1 (low arousal) to 6 (high arousal); [c]Rating of Perceived Exertion scores range from 6 (no exertion) to 20 (maximum exertion); [d]Exercise Induced Feeling Inventory scores range from 0 (do not feel) to 4 (feel very strongly); [e]Physical Activity Affective Scale consists of 12 items measured on a 5-point Likert scale (0 = strongly disagree to 4 = strongly agree) across 4 subscales “positive affect”, “tranquility”, “negative affect”, “fatigue”; [f]Subjective vitality scores range from 1 (not at all) to 7 (very true); [h]State-trait Anxiety Inventory – A higher score indicates more severe anxiety; [i]Rosenberg Self-Esteem Scale – higher scores indicate higher self-esteem; [j]Happiness Index for Koreans includes 3 components, each contain 3 items rated on a seven-point scale (“strongly disagree” to “strongly agree”), total score is value difference between positive emotions and negative emotions components; [k]Total mood disturbance calculated by summing the POMS subscale T-scores of anger, confusion, depression, fatigue, and tension and then subtracting the T-score for vigor; [l]Enjoyment scales typically range from 0 (not at all) to 10, or 100 (very much), in some cases range from 0 (not at all) to 8 (very much); [o]Perceived Restorativeness Scale 16-item distributed in 4 subscales “being-away”, “fascination”, “coherence”, and “compatibility”, in each scale 7-point scale (ranging from 0 = not at all to 6 = completely); [q]Positive and Negative Affect Scale include a brief list of 6 mood states;

[r]Activation-deactivation adjective checklist; [s]Attentional Focus Questionnaire is a 31-item measure of "association", "dissociation", "distress", it has a 7-point scale (1 = did not do this at all to 7 = I did this all the time) for each subscale; [v]Backwards Digit Span task scores from 9 (correct all digit strings recited correctly) to 0 (no digit strings recited correctly).

Discussion

This systematic review was conducted to find experimental studies exploring the effects of exercising in natural environments, in comparison to indoor environments, on mental health and well-being outcomes, from 2010 to 2017. Next, we discuss the methodologies, relevant results, underlying limitations, and suggestions for future research.

Included Studies.

The records found in one single source (Web of Science™ databases) showed an impressive number of new studies, from 2010 until 2017. This review identified 11 studies that showed results supporting previous evidence, namely, that exercising in natural environments consistently has greater improvements in affect and other well-being outcome measures, than exercising in indoor settings. However, a considerable number of studies also showed no significant effects in such measures.

Methodological Designs of the Studies.

Samples

For this review, it was decided not to include studies with an infant or adolescent sample because, as stated by Lempp, "children's ability to reflect and discuss their feelings or experiences is influenced by maturational factors. This means that child and clinician are at different developmental levels and speak "different languages". Moreover, stage-specific developmental features can impede communication. For instance, younger children may not trust unfamiliar adults, adolescents often perceive clinicians as simply another adult imposing expectations or judging them" (Lempp, de Lange, Radeloff, & Bachmann, 2012, pp. 3-4). On the other hand, virtually all other age groups are represented across studies, from young to older adults (pooled mean age of 32), with all age groups showing similar results of greater well-being improvements of exercising in the outdoor green setting, either with significant effects or not, comparing to exercising in the indoor setting.

Regarding gender, the pooled sample contains an overwhelming number of female subjects (81.9 %) which negates extrapolation of results to male populations; and regarding subjects' physical activity levels, there is considerable variation within studies, including sedentary, recreational, and athlete level, which may allow the possibility that subjects with a higher level of physical activity accounting for the greatest well-being improvements, justified by the already acquired habit of exercising. This hypothesis was not explored in included studies, as these participants may elevate group mean score of a Likert scale measure, while sedentary subjects may not experience the exercise interventions as pleasurable as the more active subjects. So, it is important to consider the role of physical activity level in future green exercise well-being research.

Duration and Exercise Type, Volume, and Intensity

In this review, four long-term studies were found, that can give an insight into the cumulative, lasting effects of exercising in both natural and indoor environments. The results may be important, because three of these studies generally use the same design and intervention, as they were conducted by the same author (Calogiuri, et al., 2015; Calogiuri, et al., 2014; Calogiuri, Nordtug, & Weydahl, 2015). Contrary to the identified short-term studies, these studies consistently showed significantly greater benefits of exercising in natural environments over indoor environments, particularly in restorativeness and affect outcomes. This seems to point to considerable long-term differences between both green and indoor exercise environments, though, at present, a limited number of studies, and heterogeneity of outcome measures, make it difficult to produce strong review and meta-analysis evidence on the effects of exercising in outdoor natural, and indoor settings.

Interventions used in selected studies include a variety of exercise types, volumes, and intensities, that, combined with the variety of sample characteristics, make the extrapolation of specific green exercise treatments, and effects to specific population groups, extremely limited.

Exercise Environments

The studies included in this systematic review showed different green outdoor environments, including urban and wild, with similar results, although almost none took into consideration quality of environment. Restorativeness of environment was studied in some studies (Calogiuri, et al., 2014; Calogiuri, et al., 2015; Calogiuri, Nordtug, & Weydahl, 2015), showing that the green environment is consistently considered the most restorative environment. Nonetheless, other features such as biodiversity, color, or temperature were not studied. According to Akpinar (Akpinar, 2016), the usage of outdoor green settings in research has varied substantially, with usually two interpretations being made concerning green spaces. One is the overarching description of nature (landscapes with vegetation, water, trees, and geological formations); and the other is the description of urban vegetation (parks and gardens), therefore, there is no precise definition of green space. Additionally, quality of green space has been characterized in a variety of ways, being measured by perceptions of “naturalness” or lack of litter, “greenness”, as having good natural lighting, and cooling potential (Mackay & Neill, 2010; Taylor & Hochuli, 2017). Perception of green space quality may also vary according to social group. Indeed, maintenance and cleanliness in urban green spaces show improved self-esteem and improve level of physical activity. Also, greater amount of urban green space has showed to be associated with less stress, while dirty natural environments show reduced improvements in self-esteem (Akpinar, 2016; Pretty, Peacock, Sellens, & Griffin, 2005).

The selected studies using simulations of outdoor natural environments in indoor settings may lack representative design, but they can be a valuable way to better control, and identify specific benefit-inducing characteristics in environments, such as quantity and quality of light, color, and natural elements, though simulation studies in this systematic review showed generally no significant differences for environment. An example is the experiment by Akers (Akers, et al., 2012) using a simulated setting a video of a course, while participants exercised on cycloergometers. The video was showed in three color filters: green, red, and gray; after the intervention, the green color showed the greatest benefits for mood, and other physiological measures in participants.

Researchers have hypothesized a greater benefit of the presence of water in outdoor natural exercise environments. This has led to the coining of the term “blue exercise”, suggesting ocean, lakes, rivers, and streams, together with vegetation, may be more associated with physical and well-being benefits, than green environments. However, recent evidence shows no differences in measures of self-esteem, stress, and mood, among various types of green and blue exercise environments, including beach, riverside, and grassland (Rogerson, Brown, Sandercock, Wooller, & Barton, 2016; White, Pahl, Ashbullby, Burton, & Depledge, 2015). Therefore, the type of natural environment may not be as important as other features of the individual, exercise, and the environment.

Outcome measures

Numerous outcome measures were used in studies, including diverse scales to measure identical states. In the domain of Mood and Affect, there were four scales used, them being the Feeling Scale (most common), Exercise-Induced Feeling Inventory, Profile of Moods States, and Physical Activity Affect Scale. Although these scales measure feeling / affect / mood states, there are construct differences which make it hard to interpret these scales' outcomes in conjunction. The same goes for Arousal, as this domain has been measured in these studies with the Felt Arousal Scale (most common), and the Activation-Deactivation Adjective Checklist. The most homogenous domain studied was perceived exertion, with Rating of Perceived Exertion being the only scale, and although it was used in it's short (1-10), and long forms (6-20), these scales share the same construct, and can easily be interpreted together. Also, perceived restorativeness was always measured with the Perceived Restorativeness Scale. In order to improve research in this topic, consensus must be reached over the most appropriate instruments to measure these different psychological states.

Other interesting mental health and well-being measures were only explored in particular cases, such as depression (Beck Depression Inventory), anxiety (State Trait Anxiety Inventory), self-esteem (Rosenberg Self-esteem Scale), happiness (Happiness Index for Koreans), and attention (Attentional Focus Questionnaire, and Backwards Digit Span Task). It is surprising to note that there is limited usage of cognitive measurements, such as memory and attention. There is lack of knowledge whether exercising in the outdoor green environment may bring greater improvement for cognitive functioning than exercising in the indoor environment, so it is recommended to explore this matter further.

Risk of Bias

Analogous to the remarks by Coon in a previous review (Coon, et al., 2011), most of the studies we found show considerable risk of bias in methods and design. There was a lack of detail in randomization processes, and no allocation concealment, which can lead to increased bias in results, as participants can make preconceptions about how they should behave during intervention, thus not participating in a natural way.

Limitations

Limitations of this study are the usage of one single online source (Web of Science™ databases), because other databases might cover research related to the topic of this review, such as Sportdiscus, Psycinfo, or Spocus, but those were not searched. Additionally, only studies in English were considered, leaving possibly relevant studies out of review.

Conclusion

In this systematic review, the most remarkable findings are the identification of four long-term studies which showed the most unequivocal greater well-being benefits of a green exercise intervention over time, when compared to an indoor exercise intervention. Another important finding was the common usage of specific outcome measures in multiple studies, like the Feeling Scale for measuring affect, Felt Arousal Scale for measuring arousal, and the Rating of Perceived Exertion for measuring perceived exertion; with the observed regular usage of certain outcome measures, it may now be possible to better analyze the data through meta-analytical methods. Several studies show no significant differences of exercising in both environments, but further meta-analysis may aggregate outcome results to show a clearer pooled effect, since, generally, studies show greater scores in mental health and well-being outcomes for green exercise than indoor exercise, despite there being no significant effects in some cases.

Although the results are promising, we noted that studies revealed substantial limitations in design, and do not account for important features of the environment such as temperature, color, quality, and meteorological conditions; also, there appears to be an imbalance in gender, with overwhelmingly female samples. Although there seems to be a trend in outcome measures used, a considerable number of different instruments are used to measure same domains.

Finally, to address the limited number and quality of studies, additional long-term, including multiple population groups, and well-designed research is needed in order to validate data and extrapolate to practical application by exercise and health professionals, urban designers, and policy makers; furthermore, more interest should be paid to changes in cognitive measures (attention and memory) of exercising out in nature, and indoors, as well as other features of the environment as cleanliness, perceived restorativeness, color, and temperature, as suggested in previous studies (Akers, et al., 2012; Akpinar, 2016; Calogiuri, Nordtug, & Weydahl, 2015).

Study 2. Meta-analysis

Introduction

In study 1, the aim was to conduct a systematic review on experimental studies published since 2010, comparing green exercise to indoor exercise, on outcomes of mental health and well-being, in order to update the review made by Coon (Coon, et al., 2011). 11 studies were collected and reviewed, verifying most remarks made by these authors, such as overall greater benefits in the outcomes for green exercise. However, there were limitations in studies' methodologies and heterogeneity in the outcome measures.

The aggregate number of studies of our previously presented systematic review (study 1), together with those experimental studies from the systematic review of Coon (2011), allow for a meta-analysis of pooled data, since there are the same outcome measures present in multiple studies, such as those from the Feeling Scale, Felt Arousal Scale, Activation-Deactivation Adjective Checklist, and Rating of Perceived Exertion.

The aim of this study was to collect data of controlled trials identified in two previous systematic reviews, and conduct meta-analysis in most common outcome measures, specifically the Feeling Scale (Affect), Felt Arousal Scale (Arousal), Activation-Deactivation Adjective Checklist (Arousal), and Rating of Perceived Exertion (perceived exertion), to quantify differences in these measures when exercising in outdoor natural, and indoor environments.

Method

Pool of Studies.

11 studies were collected from the systematic review carried out in study 1, additionally to those 11 studies from the systematic review of Coon and colleagues (2011).

Eligibility criteria.

To perform meta-analysis on the pool of studies, and reduce bias to a minimum, studies were selected based on similarity of study design, exercise intensity, outcome measures, and time-point measurements. Therefore, included studies used (1) repeated measures within-subjects designs, (2) one same exercise routine in both green, and indoor settings, (3) exercise intensity under 75 % VO_2peak, or equivalent, and (4) the same version of outcome measure. High exercise intensity was an exclusion criterion because maximal and sub-maximal physical exertion has been showed to increase negative affect, and change attentional focus to a more internal awareness (Hutchinson & Tenenbaum, 2007; Ekkekakis, Parfitt, & Petruzzello, 2011). Also, included measures had the same version of the same instrument, because scientific instruments and scales are frequently updated, for greater objectivity, and to implement new theoretical models. Common time-point measurements between studies were analyzed, provided there was enough data on at least three studies.

Data extraction.

Some authors were contacted to provide data, which they kindly offered (Turner & Stevinson, 2017). Data extracted included sample N, and time-point measurements of “pre-“, “during-“, “end-“, and “post-exercise”, in both natural and indoor settings. In studies where no exact mid-point exercise measurement was available, but showing multiple “during-exercise” time-points, the criterion was to include the “during-exercise” measurement closest to start of exercise. This was to avoid confounding effects of tiredness over the outcome measure.

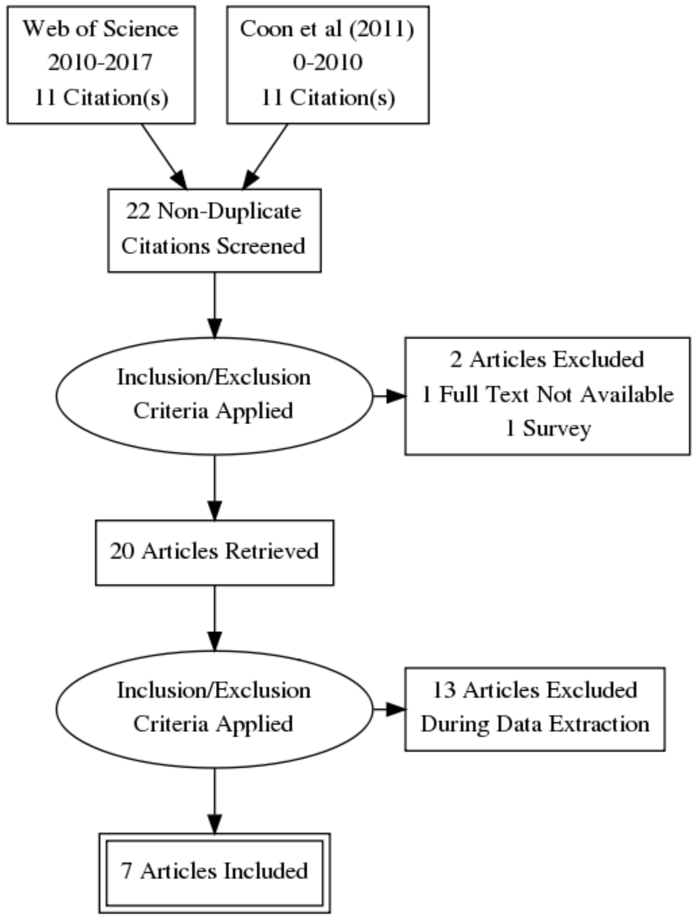
However, in the study of Turner et al. (2017), exercise intensity started as self-selected, and then, halfway during exercise, participants were asked to exercise at maximum exertion until the end of exercise. In this case, only data from the first half of the exercise was extracted for analysis, as stated in the eligibility criteria. Rating of Perceived Exertion (Borg, 1990) data would not be extracted when used to establish exercise intensity during study interventions, but as an outcome measure.

Results

Included Studies.

From the 22 pooled studies, two were excluded from the review by Coon (2011) because one was a survey (Hug, Hartig, Hansmann, Seeland, & Hornung, 2009), and for the other, it was not possible to find a full text copy of the study by (McMurray, Berry, Vann, Hardy, & Sheps, 1988) (Figure 2). Subsequently, 13 studies were excluded when screened against eligibility criteria for data extraction, and meta-analysis was performed with data from the remaining seven studies (Table 6).

Figure 2. Flowchart of Selection of Experimental Studies for Meta-analysis on Green Exercise



Data Analysis.

The meta-analysis was carried out with a specific software (Comprehensive Meta-analysis version 2 (2014) Englewood, NJ: Biostat, Available from http://www.comprehensive.com). Effect sizes were expressed as Standard Difference in Means (SDM), with positive values showing higher score, or greater increase in score for exercising in the green environment, than exercising in the indoor environment. Despite efforts to homogenize data, the interventions had different characteristics, so a random effects model was used.

Table 6. Interventions Details and Measures of Studies Included in Meta-analysis

Study, year	Exercise	Intensity	Outcome	Time-point measurements
White, 2015	15 min cycloergometer	Self-selected	Feeling Scale; Felt Arousal Scale;	Pre, During, End, Post 5’
			Rating of Perceived Exertion	During, End
Williams, 2011	30 min run	60-70% MHR	Feeling Scale; Felt Arousal Scale;	Pre, During, End, Post 10’
			Activation-Deactivation Adjective Checklist	Pre, Post 10’
			Rating of Perceived Exertion	During, End
Focht, 2009	10 min walk	Self-selected	Feeling Scale; Felt Arousal Scale;	Pre, During, End, Post 10’
			Rating of Perceived Exertion	During, End
Turner, 2017	3 km run	Self-selected	Feeling Scale; Felt Arousal Scale;	Pre, End
			Rating of Perceived Exertion	End
Plante, 2007	20 min walk	60-70% MHR	Activation-Deactivation Adjective Checklist	Pre, Post 0’
Rogerson, 2016	15 min cycloergometer	50% HRR	Rating of Perceived Exertion	During, End
Rogerson, 2015	15 min treadmill run	60% VO_2peak	Rating of Perceived Exertion	End

Note: MHR = Maximum Heart Rate; HRR = Heart Rate Reserve; VO_2peak = Peak O_2 Consumption

Outcome Measures.

Feeling Scale (Hardy & Rejeski, 1989).

The Feeling Scale is an 11-point Likert-type scale. It assesses how the subject feels at the moment, and therefore can be used to measure mood responses during exercise. The scale ranges from +5 (very well), to -5 (very bad). Data were extracted from four studies, with three showing mean values for pre-, during-, end-, and post-exercise (White, Pahl, Ashbullby, Burton, & Depledge, 2015; Williams, 2011; Focht, 2009), and one study showing only data for pre-, and end-exercise (Turner & Stevinson, 2017). Meta-analysis showed the following effect sizes in the following time-points: “pre-to-during” exercise SDM = 0.45 ($p = 0.045$) (Table 7, Figure 3); “during-to-end” exercise SDM = 0.066 ($p = 0.645$) (Table 8, Figure 4); “end-to-post” exercise SDM = 0.272 ($p = 0.059$) (Table 9, Figure 5); “pre-to-post” exercise SDM = 0.331 ($p = 0.138$) (Table 10, Figure 6); “during-to-post” exercise SDM = 0.340 ($p = 0.018$) (Table 11, Figure 7); “pre-to-end” exercise SDM = 0.405 ($p = 0.023$) (Table 12, Figure 8).

Table 7. Feeling Scale "Pre-to During" Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.882	0.244	0.059	0.405	1.359	3.622	0.000	34.45
Williams, 2011	0.166	0.278	0.077	-0.378	0.711	0.599	0.549	30.71
Focht, 2009	0.274	0.240	0.058	-0.197	0.744	1.139	0.255	34.84
TOTAL	0.450	0.225	0.051	0.010	0.891	2.004	0.045	

Note: SDM = Standard Mean Difference; SE = Standard Error.

Figure 3. Feeling Scale "Pre-to-During" Tree Plot

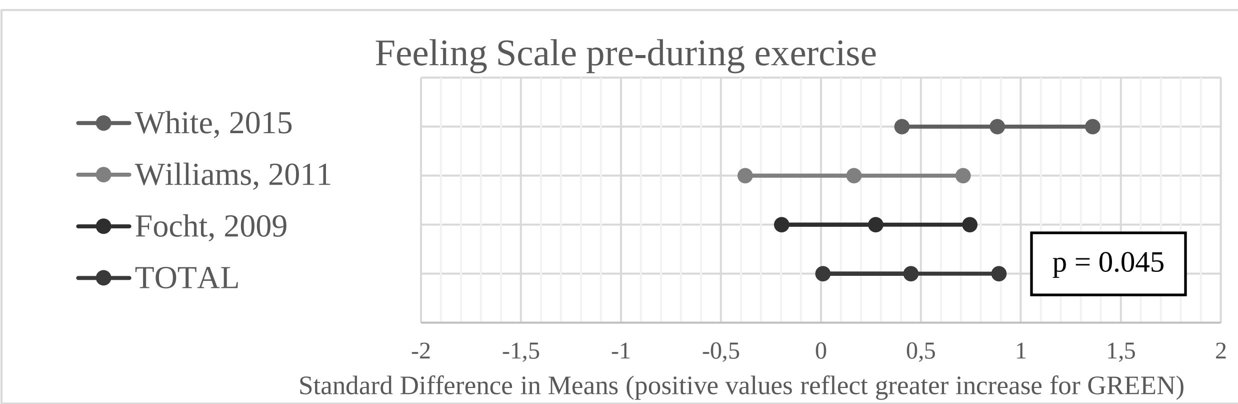


Table 8. Feeling Scale “During-To-End” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.033	0.233	0.054	-0.423	0.489	0.142	0.887	37.78
Williams, 2011	0.028	0.277	0.077	-0.516	0.571	0.099	0.921	26.55
Focht, 2009	0.129	0.239	0.057	-0.340	0.598	0.539	0.590	35.67
TOTAL	0.066	0.143	0.020	-0.214	0.346	0.460	0.645	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 4. Feeling Scale "During-to End" Tree Plot

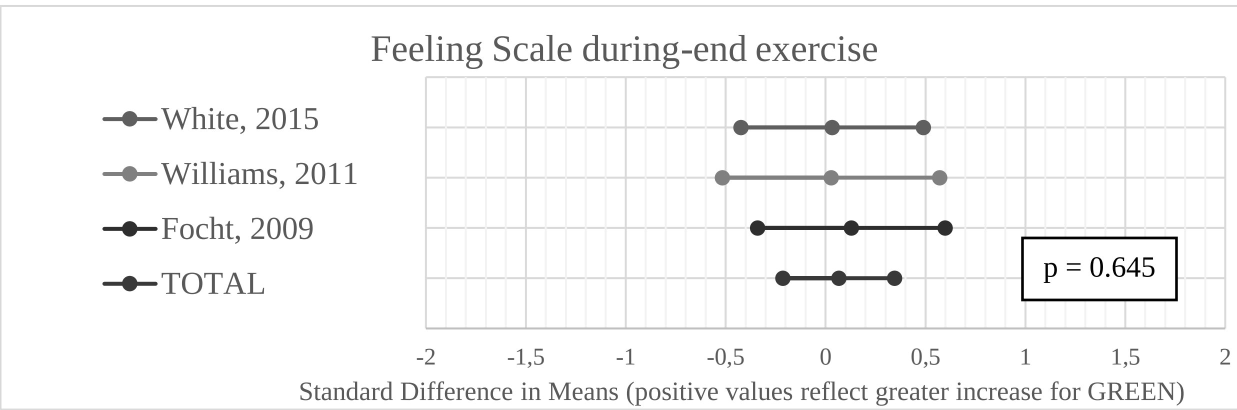


Table 9. Feeling Scale “End-To-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.444	0.235	0.055	-0.017	0.905	1.888	0.059	37.28
Williams, 2011	0.107	0.278	0.077	-0.437	0.651	0.386	0.700	26.80
Focht, 2009	0.215	0.240	0.057	-0.254	0.685	0.898	0.369	35.92
TOTAL	0.272	0.144	0.021	-0.010	0.553	1.891	0.059	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 5. Feeling Scale "End-to-Post" Tree Plot

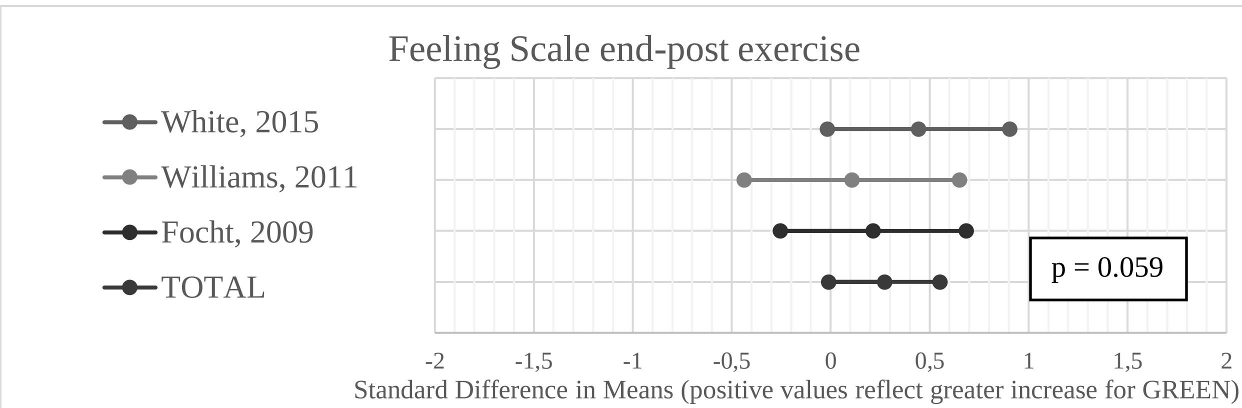


Table 10. Feeling Scale “Pre-To-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.756	0.241	0.058	0.284	1.228	0.142	0.002	34.64
Williams, 2011	0.117	0.278	0.077	-0.427	0.661	0.421	0.674	30.55
Focht, 2009	0.095	0.239	0.057	-0.374	0.564	0.396	0.692	34.81
TOTAL	0.331	0.223	0.050	-0.106	0.767	1.485	0.138	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 6. Feeling Scale "Pre-to-Post" Tree Plot

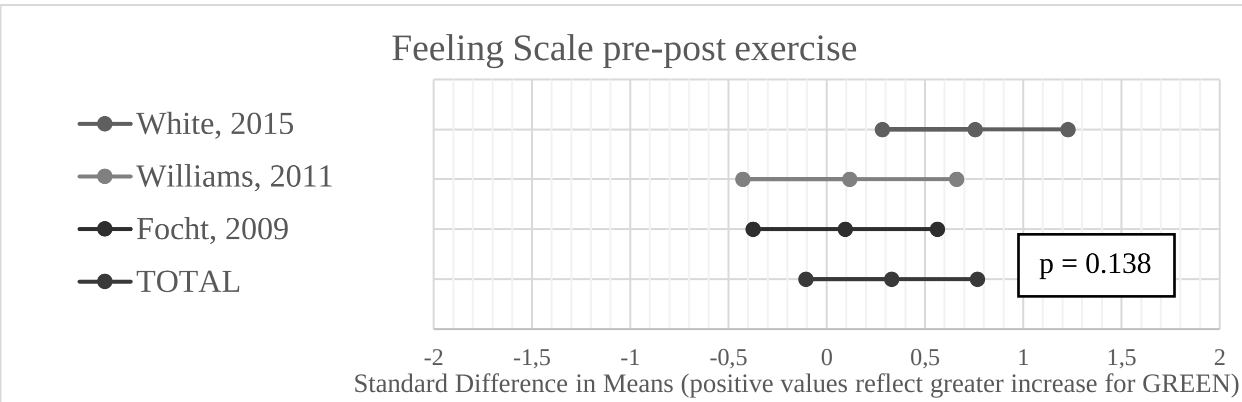


Table 11. Feeling Scale “During-To-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.491	0.236	0.056	0.029	0.954	2.083	0.037	37.30
Williams, 2011	0.078	0.277	0.077	-0.466	0.622	0.281	0.779	26.98
Focht, 2009	0.379	0.241	0.058	-0.094	0.852	1.572	0.116	35.71
TOTAL	0.340	0.144	0.021	0.057	0.622	2.357	0.018	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 7. Feeling Scale "During-to-Post" Tree Plot

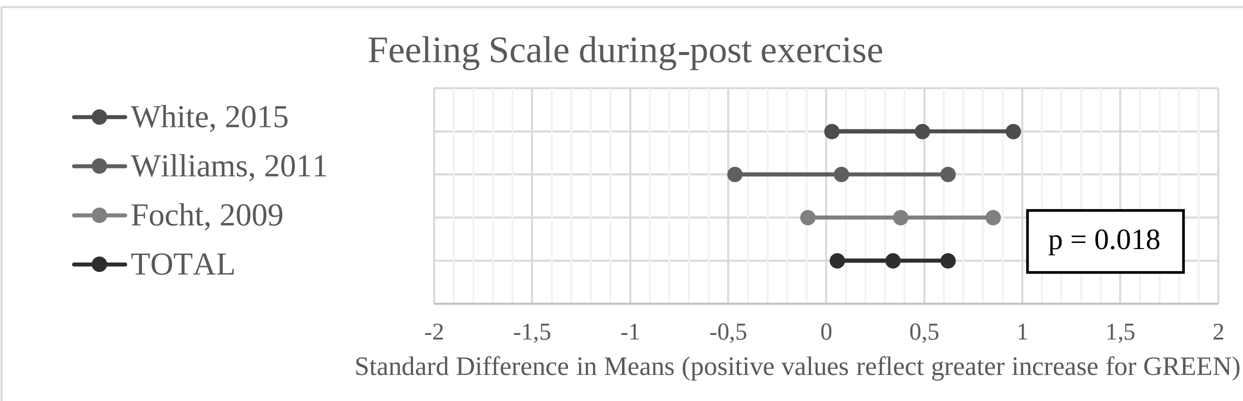
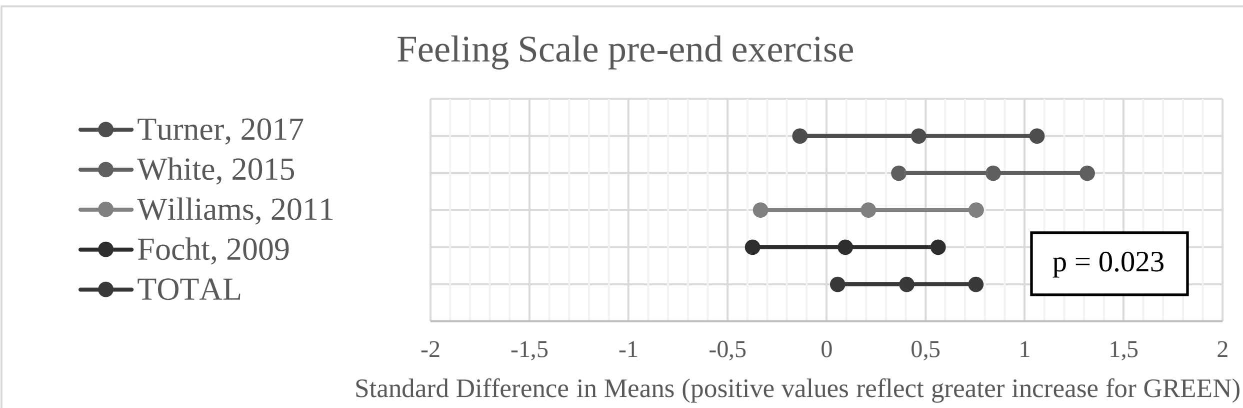


Table 12. Feeling Scale "Pre-to-End" Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
Turner, 2017	0.465	0.306	0.093	-0.134	1.063	1.520	0.128	21.11
White, 2015	0.841	0.243	0.059	0.365	1.316	3.466	0.001	27.43
Williams, 2011	0.211	0.278	0.077	-0.334	0.756	0.759	0.448	23.63
Focht, 2009	0.095	0.239	0.057	-0.374	0.564	0.397	0.691	27.82
TOTAL	0.405	0.178	0.032	0.056	0.754	2.278	0.023	

Note: SMD = Standard Mean Difference; SE = Standard Error

Figure 8. Feeling Scale "Pre-to-End" Tree Plot



Felt Arousal Scale (Svebak & Murgatroyd, 1985)

The Felt Arousal Scale is a six-point scale, which measures arousal/activation. It varies between 1 (low activation) and 6 (high activation). Higher arousal can be experienced as anger, excitement, or anxiety, and little arousal can be experienced as boredom, relaxation, or calmness. Data were extracted from four studies, with three studies showing mean values for pre-, during-, end-, and post-exercise (White, Pahl, Ashbullby, Burton, & Depledge, 2015; Williams, 2011; Focht, 2009), and one study showing only data for pre-, and end-exercise (Turner & Stevinson, 2017). Meta-analysis showed the following effect sizes in the following time-points: “pre-to-during” exercise SDM = 0.229 ($p = 0.110$) (Table 13, Figure 9); “during-to-end” exercise SDM = 0.170 ($p = 0.236$) (Table 14, Figure 10); “end-to-post” exercise SDM = 0.161 ($p = 0.262$) (Table 15, Figure 11); “pre-to-post” exercise SDM = 0.242 ($p = 0.091$) (Table 16, Figure 12); “during-to-post” exercise SDM = 0.158 ($p = 0.269$) (Table 17. Figure 13); “pre-to-end” exercise SDM = 0.102 ($p = 0.431$) (Table 18, Figure 14).

Table 13. Felt Arousal Scale “Pre-to-During” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
White, 2015	0.030	0.233	0.054	-0.426	0.486	0.129	0.898	38.13
Williams, 2011	0.443	0.281	0.079	-0.107	0.993	1.579	0.114	26.16
Focht, 2009	0.286	0.240	0.058	-0.185	0.757	1.190	0.234	35.71
TOTAL	0.229	0.104	0.021	-0.052	0.511	1.598	0.110	

Note: SMD = Standard Mean Difference; SE = Standard Error

Figure 9. Felt Arousal Scale "Pre-to-During" Tree Plot

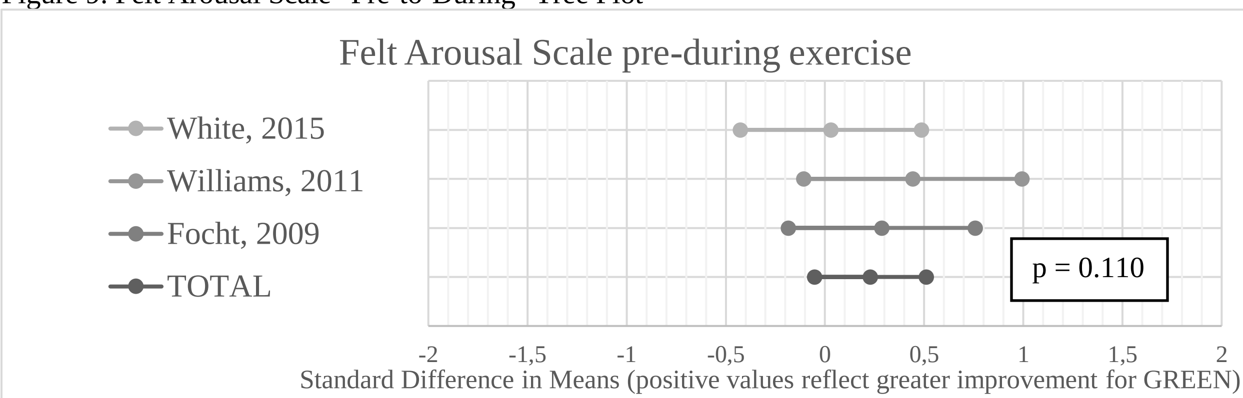


Table 14. Felt Arousal Scale “During-to-End” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.057	0.233	0.054	-0.399	0.513	0.244	0.807	37.95
Williams, 2011	0.372	0.280	0.078	-0.176	0.921	1.331	0.183	26.22
Focht, 2009	0.141	0.239	0.057	-0.328	0.610	0.589	0.556	35.82
TOTAL	0.170	0.143	0.021	-0.111	0.450	1.185	0.236	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 10. Felt Arousal Scale "During-to-End" Tree Plot

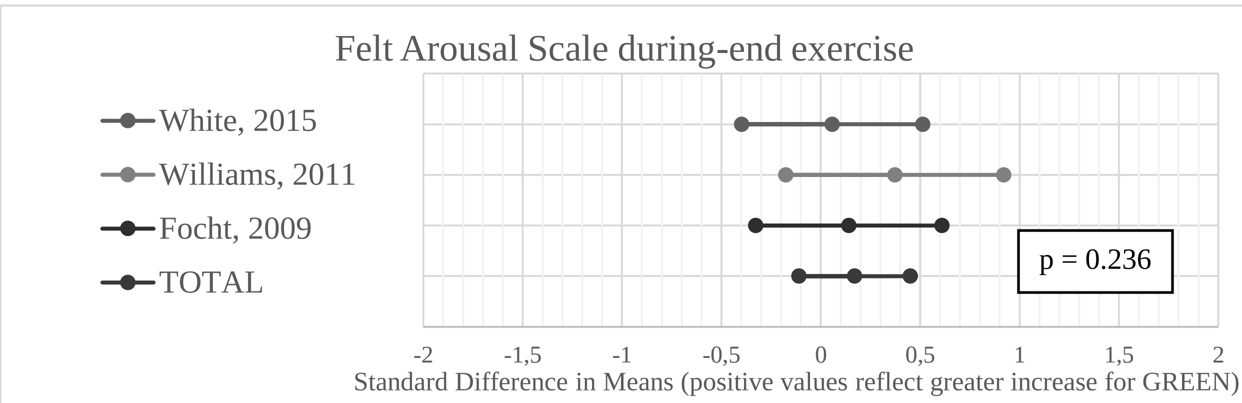


Table 15. Felt Arousal Scale "End-to-Post" Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.074	0.233	0.054	-0.382	0.530	0.317	0.751	37.89
Williams, 2011	0.139	0.278	0.077	-0.406	0.683	0.499	0.617	26.58
Focht, 2009	0.270	0.240	0.058	-0.201	0.740	1.123	0.262	35.54
TOTAL	0.161	0.143	0.020	-0.120	0.441	1.122	0.262	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 11. Felt Arousal Scale "End-to-Post" Tree Plot

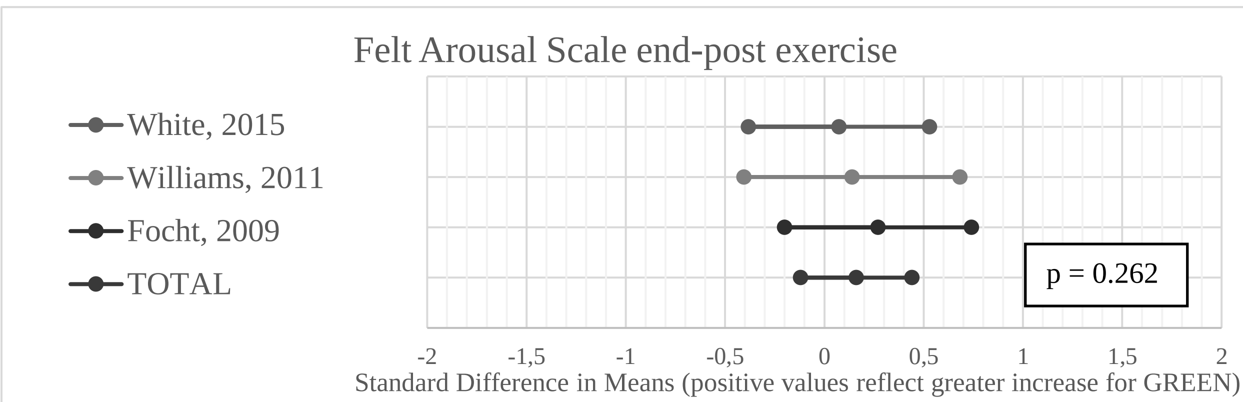


Table 16. Felt Arousal Scale "Pre-to-Post" Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.166	0.233	0.054	-0.290	0.623	0.713	0.476	37.94
Williams, 2011	0.185	0.278	0.077	-0.360	0.730	0.665	0.506	26.64
Focht, 2009	0.368	0.241	0.058	-0.105	0.840	1.525	0.127	35.42
TOTAL	0.242	0.143	0.021	-0.039	0.524	1.690	0.091	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 12. Felt Arousal Scale "Pre-to-Post" Tree Plot

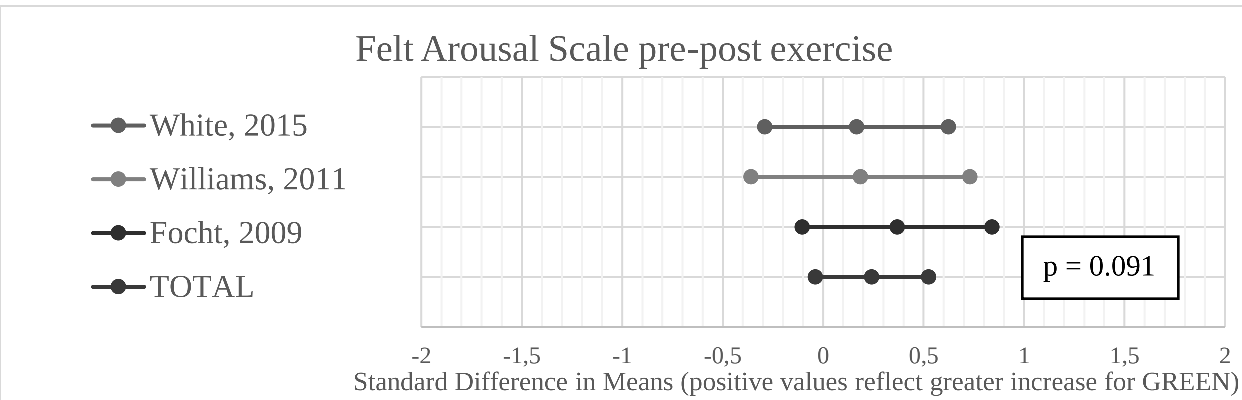


Table 17. Felt Arousal Scale “During-to-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
White, 2015	0.138	0.233	0.054	-0.318	0.595	0.595	0.552	37.79
Williams, 2011	0.213	0.278	0.077	-0.332	0.758	0.765	0.445	26.47
Focht, 2009	0.139	0.239	0.057	-0.330	0.608	0.580	0.562	35.74
TOTAL	0.158	0.143	0.020	-0.122	0.439	1.106	0.269	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 13. Felt Arousal Scale "During-to-Post" Tree Plot

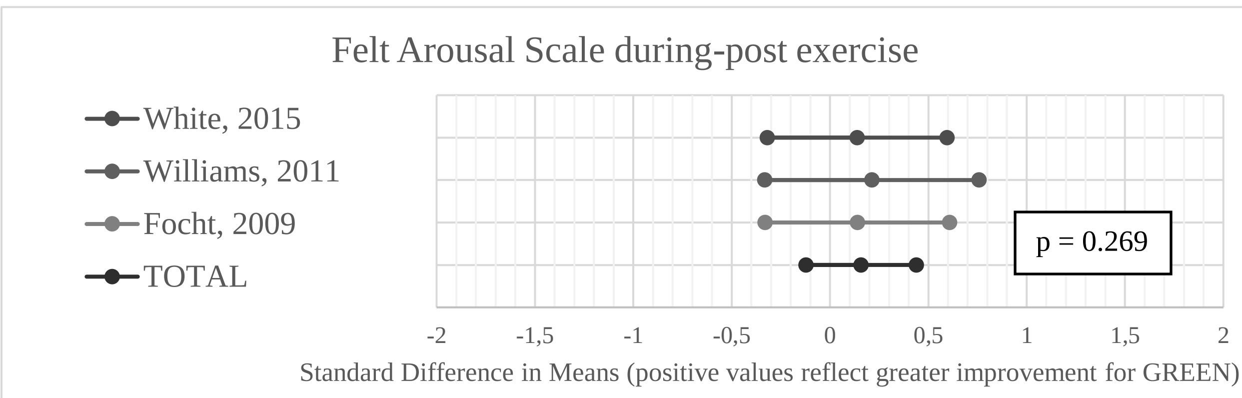
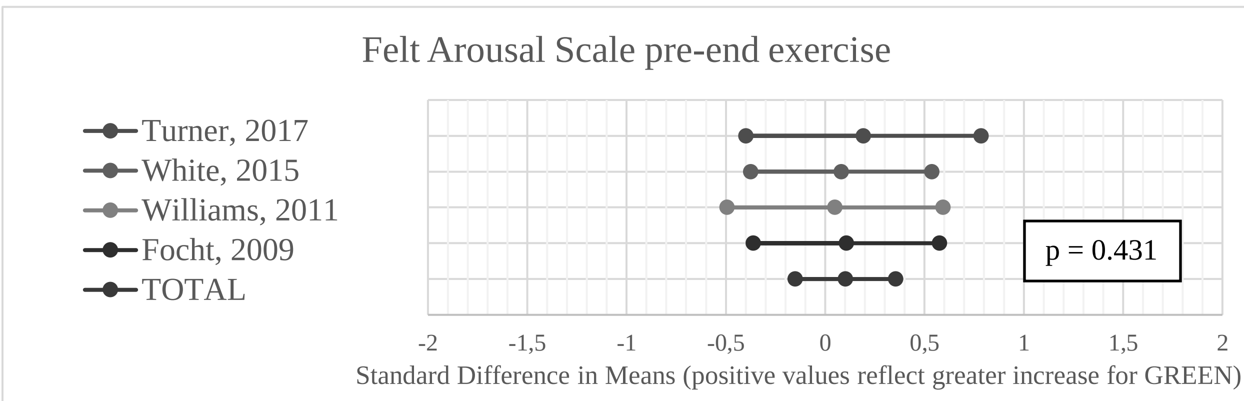


Table 18. Felt Arousal Scale “Pre-to-End” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-value	Relative Weight
Turner, 2017	0.192	0.302	0.091	-0.400	0.785	0.637	0.524	18.28
White, 2015	0.081	0.233	0.054	-0.375	0.537	0.349	0.727	30.86
Williams, 2011	0.049	0.277	0.077	-0.495	0.593	0.177	0.860	21.69
Focht, 2009	0.106	0.239	0.057	-0.363	0.575	0.442	0.658	29.17
TOTAL	0.102	0.129	0.017	-0.152	0.355	0.787	0.431	

Note: SMD = Standard Mean Difference; SE = Standard Error

Figure 14. Felt Arousal Scale "Pre-to-End" Tree Plot



Activation-Deactivation Adjective Checklist (Thayer, 1986)

The AD-ACL has four subscales of states of activation: Energy, Calmness, Tiredness, and Tension. Each subscale shows five mood sensations, which appear as adjectives. The subjects are to select, from 0 to 4, how much they agree that they are experiencing said adjectives, in each of the four subscales. Data were extracted from three studies showing mean values for pre-, and post-exercise. Two studies were analyzed (Williams, 2011; Plante, et al., 2007), with two sets of data extracted from Plante (2007). Meta-analysis showed the following effect sizes in the following subscales: Calmness “pre-to post” exercise SDM = 0.398 (p = 0.142) (Table 19, Figure 15); Energy “pre-to-post” exercise SDM = 0.347 (p =0.079) (Table 20, Figure 16); Tension “pre-to-post” exercise SDM = -0.187 (p = 0.271) (Table 21, Figure 17); Tiredness “pre-to-post” exercise SDM = -0.161 (p = 0.342) (Table 22, Figure 18).

Table 19. Calmness (AD-ACL) “Pre-To-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
Williams, 2011	0.266	0.279	0.078	-0.280	0.812	0.954	0.340	35.23
Plante, 2007 (1)	0.009	0.302	0.091	-0.582	0.600	0.031	0.975	33.12
Plante, 2007 (2)	0.953	0.318	0.101	-0.330	1.577	2.996	0.003	31.65
TOTAL	0.398	0.271	0.073	-0.133	0.929	1.470	0.142	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 15. Calmness (AD-ACL) "Pre-to-Post" Tree Plot

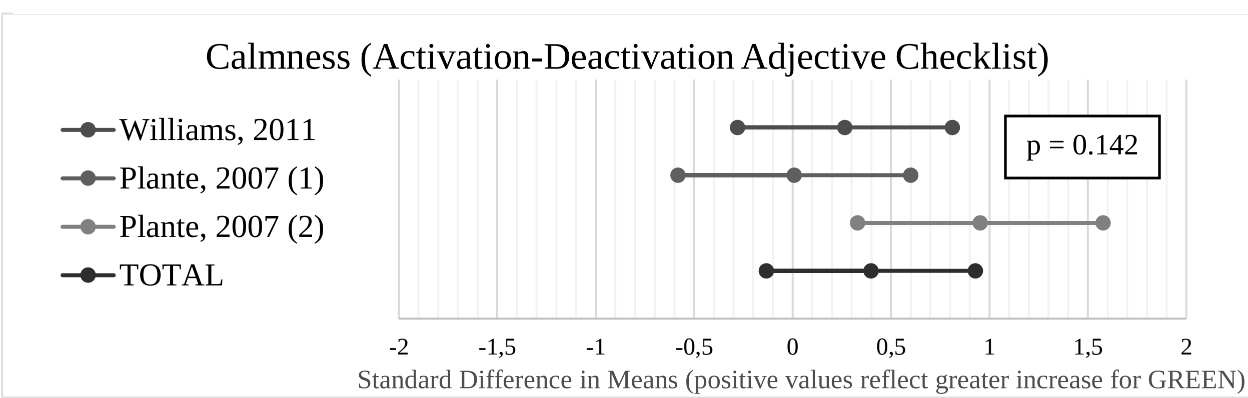


Table 20. Energy (AD-ACL) “Pre-To-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
Williams, 2011	0.719	0.286	0.082	0.158	1.280	2.514	0.012	35.14
Plante, 2007 (1)	0.086	0.302	0.091	-0.505	0.677	0.285	0.776	32.48
Plante, 2007 (2)	0.205	0.302	0.091	-0.388	0.797	0.677	0.498	32.38
TOTAL	0.347	0.198	0.039	-0.040	0.734	1.756	0.079	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 16. Energy (AD-ACL) "Pre-to-Post" Tree Plot

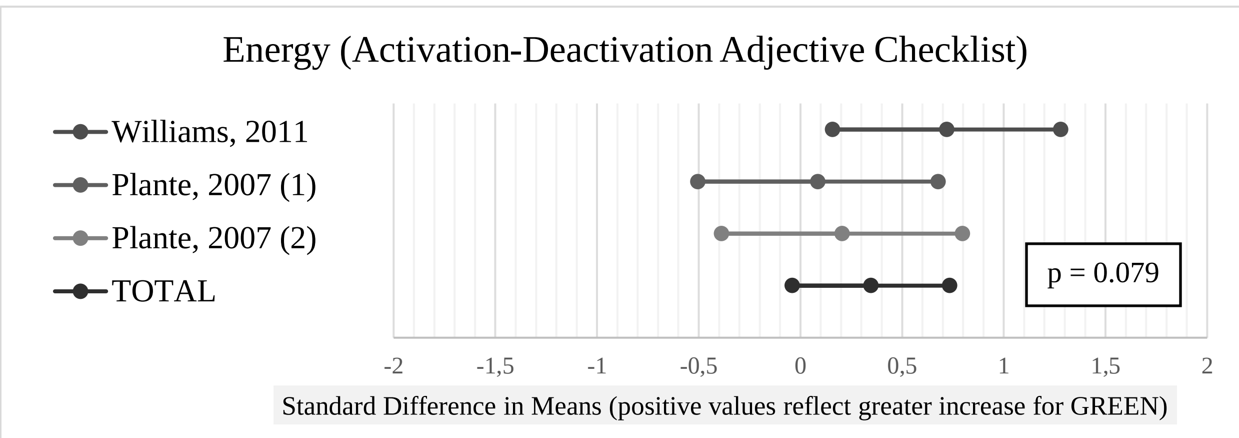


Table 21. Tension (AD-ACL) “Pre-To-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
Williams, 2011	-0.058	0.277	0.077	-0.602	0.486	-0.209	0.834	37.41
Plante, 2007 (1)	-0.421	0.305	0.093	-1.019	0.176	-1.381	0.167	30.98
Plante, 2007 (2)	-0.109	0.302	0.091	-0.701	0.482	-0.362	0.717	31.62
TOTAL	-0.187	0.170	0.029	-0.519	0.146	-1.100	0.271	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 17. Tension (AD-ACL) "Pre-to-Post" Tree Plot.

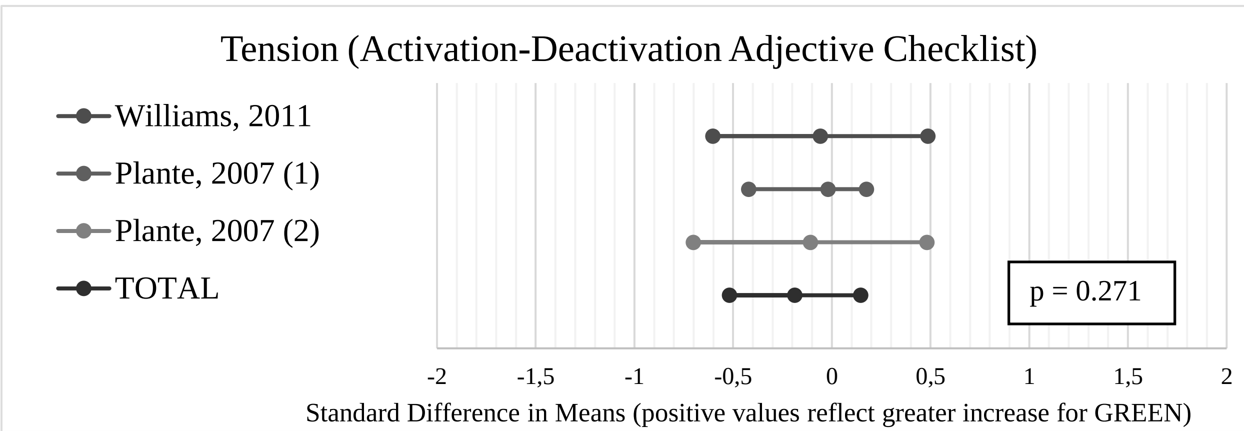
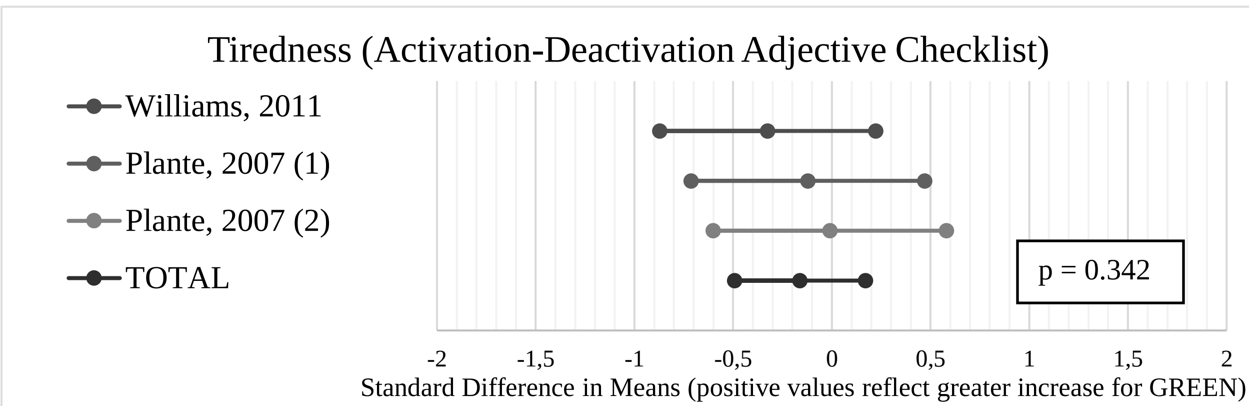


Table 22. Tiredness (AD-ACL) “Pre-To-Post” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
Williams, 2011	-0.325	0.279	0.078	-0.872	0.222	-1.164	0.244	36.86
Plante, 2007 (1)	-0.121	0.302	0.091	-0.713	0.470	-0.402	0.688	31.54
Plante, 2007 (2)	-0.010	0.302	0.091	-0.601	0.581	-0.033	0.974	31.60
TOTAL	-0.161	0.169	0.029	-0.493	0.171	-0.951	0.342	

Note: SMD = Standard Mean Difference; SE = Standard Error.

Figure 18. Tiredness (AD-ACL) "Pre-to-Post" Tree Plot



Rating of Perceived Exertion (Borg, 1990)

The Borg scale is a Likert-type scale widely used to control intensity of physical exercise and assess exercise exertion. The scale has an interval of 6 (no exertion at all) to 20 (maximal exertion). Data were extracted from six studies, with four studies showing mean values for during-to-end exercise (White, Pahl, Ashbullby, Burton, & Depledge, 2015; Williams, 2011; Focht, 2009; Rogerson, Gladwell, Gallagher, & Barton, 2016), and six studies showing only data for end exercise (Turner & Stevinson, 2017; Focht, 2009; Rogerson & Barton, 2015; Rogerson, Gladwell, Gallagher, & Barton, 2016; White, Pahl, Ashbullby, Burton, & Depledge, 2015; Williams, 2011). Meta-analysis showed the following effect sizes in the following time-points: "during-to-end" exercise SDM = -0.119 ($p = 0.355$) (Table 23, Figure 19); "end" exercise SDM = -0.242 ($p = 0.033$) (Table 24, Figure 20).

Table 23. Rating Of Perceived Exertion (RPE) "During-To-End" Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
Rogerson, 2016	-0.136	0.289	0.084	-0.703	0.430	-0.472	0.637	19.66
White, 2015	-0.096	0.233	0.054	-0.552	0.360	-0.413	0.680	30.35
Williams, 2011	-0.107	0.278	0.077	-0.651	0.437	-0.384	0.701	21.32
Focht, 2009	-0.139	0.239	0.057	-0.608	0.330	-0.580	0.562	28.67
TOTAL	-0.119	0.128	0.016	-0.370	0.133	-0.925	0.355	

Nota: SMD = Standard Mean Difference; SE = Standard Error.

Figure 19. Rating Of Perceived Exertion (RPE) "Pre-to-Post" Tree Plot

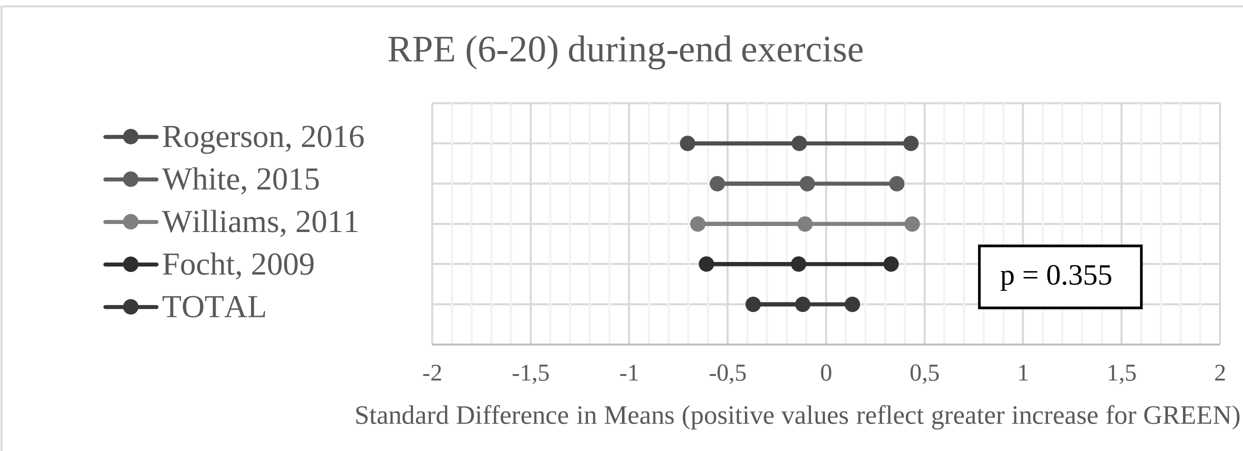
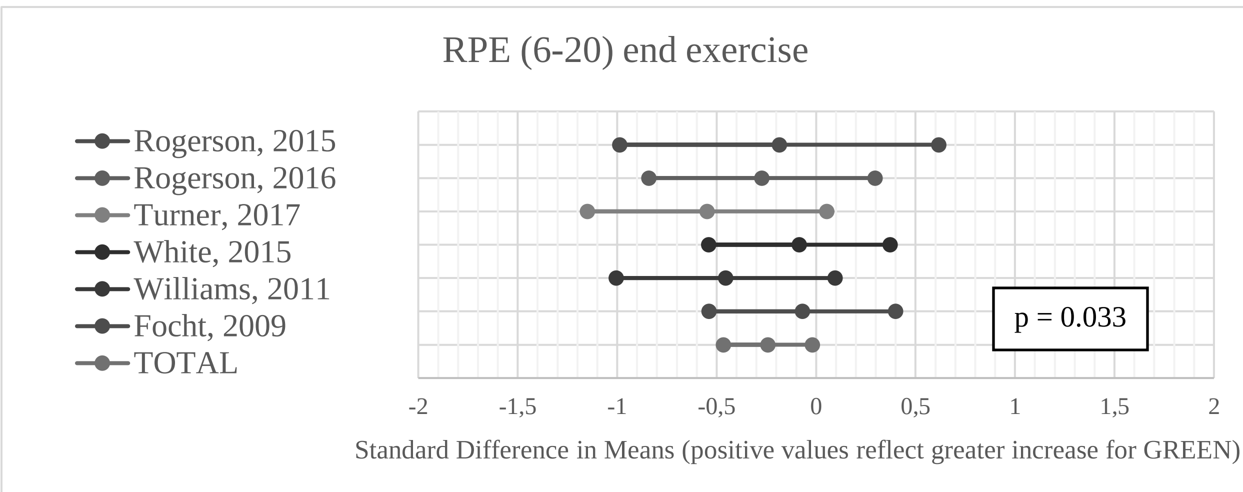


Table 24. Rating of Perceived Exertion (RPE) “End” Statistics of Differences Between Exercise Environments

Study	Statistics for each study							
	SDM	SE	Variance	Lower limit	Upper limit	Z-value	p-Value	Relative weight
Rogerson, 2015	-0.185	0.409	0.167	-0.987	0.617	-0.452	0.651	7.75
Rogerson, 2016	-0.273	0.290	0.084	-0.841	0.296	-0.940	0.347	15.42
Turner, 2017	-0.548	0.307	0.094	-1.150	0.054	-1.783	0.075	13.75
White, 2015	-0.084	0.233	0.054	-0.540	0.372	-0.361	0.718	23.97
Williams, 2011	-0.455	0.281	0.079	-1.005	0.096	-1.619	0.105	16.43
Focht, 2009	-0.069	0.239	0.057	-0.538	0.399	-0.290	0.771	22.68
TOTAL	-0.242	0.114	0.013	-0.466	-0.019	-2.128	0.033	

Nota: SMD = Standard Mean Difference; SE = Standard Error.

Figure 20. Rating Of Perceived Exertion (RPE) “End” Tree Plot



Discussion

This study provided a quantitative analysis of studies exploring the mental well-being effects of exercising in outdoor green, and indoor environments. We examined the influence of engaging in a specific exercise routine in affect, arousal, and physical exertion outcome measures. In general, results show green exercise promotes significantly greater improvements in affect and physical exertion, in specific time-points of exercise session. Next we discuss results, limitations, and suggestions for further research.

Included Studies.

The studies used for this meta-analysis resulted from the combined pool of studies from a previous systematic review (Coon, et al., 2011), and the systematic review carried out in study 1. Following eligibility criteria, seven studies were analyzed, which were the result of joining those with identical design (repeated measures within-subjects design), interventions (one session of a specific exercise routine in each condition –green and indoor environments), moderated exercise intensity (below 75% VO_2peak or similar), time-point measurements ("pre-", "during-", "end-", "post-exercise"), and outcome measures (variables from Feeling Scale, Felt Arousal Scale, Activation-Deactivation Adjective Checklist, Rating of Perceived Exertion). These criteria allowed extracted data to have been produced through fairly similar conditions, although participants in different studies may still engage in different type and duration of exercise, and natural environments may show differences in features among studies, as well as indoor environments.

Data Analysis.

There were differences in studies' interventions, therefore a random effects model was used in data treatment. Although the number of analyzed studies is small, it was possible to perform a meta-analysis in the selected outcome measures, under similar conditions. Each analysis contained data from three to six studies, on differences between time-points, which allowed for examination of the progression of specific outcome measure scores through the entire interventions. Selected outcome measures were present in more studies than those selected, which were excluded due to unsuitability of study design, or lack of extractable data. For example, Feeling Scale was present in several long-term studies, where data often was shown as a mean of consecutive exercise sessions. Those data could not be analyzed in conjunction with single-episode exercise interventions.

Measures.

Feeling Scale (Hardy & Rejeski, 1989)

Analysis of the FS showed considerable differences in affect between exercise environments, in specific time-points. Exercising in the outdoor natural environment significantly increased positive affect in the first half of exercise session, resulting in an estimated difference in scale score of positive 0.45 points. For the second half of exercise session, no significant differences in exercise environment were found, presumably because accumulated exertion increased negative affect, as observed in previous studies (Ekkekakis, Parfitt, & Petruzzello, 2011). However, exercising in the green environment showed significantly greater affect than exercising indoors for the complete duration of the exercise session, resulting in a difference in scale of positive 0.41 points. Positive affect increased after exercise, possibly because subjects rested, and physical exertion was lower. In the same manner, affect significantly increased from middle of exercise to post exercise (Ulrich, 1983).

Felt Arousal Scale (Svebak & Murgatroyd, 1985)

Analysis of the FAS showed no significant differences for exercise environment in any of six intervention time-points, including “pre-“, “mid-“, “end-“, and “post-exercise”. These results are consistent with data from individual studies and may indicate that both the green and indoor environments are perceived as unthreatening, and can promote calm and tranquility through lower perceived arousal, which is in line with Ulrich’s Stress Recovery Theory (Ulrich, 1983; Lacharité-Lemioux, Brunelle, & Dionne, 2014).

Activation-Deactivation Adjective Checklist (Thayer, 1986)

Analysis of the ADACL showed similar results to the FAS, as both are scales to measure activation / arousal. However, this analysis had the less data available, only including pre- and post-exercise measurements. So, it was not possible to explore any other time-points during intervention.

Rating of Perceived Exertion (Borg, 1990)

Analysis of the RPE (6-20) showed overall increased physical exertion while exercising in the indoor environment, including a significant increase in end-exercise time-point. This effect is reflected as an estimated additional 0.24 point in RPE. This result is supported by previous suggestions that features of the green environment such as pleasantness and biodiversity may lower stress, increase affect, and therefore shift the attention focus externally (Hutchinson & Tenenbaum, 2007; Ulrich, et al., 1991).

Limitations

Limitations of this study were the few data sources, which resulted in analyses lacking statistical strength and representativeness. Also, the individual differences in study design, and intervention of selected studies may increase bias in results, despite efforts to standardize data.

Conclusion

Results interestingly show that exercising in the green environment may significantly improve affect, when compared to exercising in the indoor environment. Additionally, exercising in the natural environment may also show significantly lower perceived exertion. Nonetheless, these results should be considered as preliminary, because of the limited number of analyzed studies. We suggest that more research be carried out, conducting experimental studies on the influence of exercising in outdoor natural and indoor environments, to better quantify benefits.

General Discussion

Coon and colleagues (Coon, et al., 2011) conducted a systematic review of 11 studies exploring differences in mental well-being of exercising in outdoor natural environments, and indoor environments. After qualitative analysis, green exercise showed greater improvements for mental well-being than indoor exercise. However, the authors concluded that there were considerable limitations in methodologies within selected studies, and the high number of outcome measures made it impossible to perform meta-analysis on outcome data.

In the present thesis, a systematic review (study 1) and a meta-analysis (study 2) were conducted. Study 1 collected 11 experimental studies following methods based, and refined, from Coon and colleagues' review. Results confirmed previous suggestions that green exercise may offer greater improvements for mental well-being, although methodologies and number of outcome measures were still limiting the analysis. Study 2 used the pool of 22 gathered studies in the previous two systematic reviews, in order to perform meta-analysis, and four outcome measures (Feeling Scale, Felt Arousal Scale, Activation-Deactivation Adjective Checklist, and Rating of Perceived Exertion) were analyzed within seven studies. Meta-analysis results showed that green exercise significantly improves affect (as measured by the Feeling Scale), and perceived exertion (as measured by Rating of Perceived Exertion), in comparison to indoor exercise, while arousal showed no significant effects for environment.

The results of the two studies carried out here corroborate suggestions from Attention Restoration Theory, Stress Recovery Theory, and Biophilia, and can be adequately integrated in an ecological dynamics framework. The environment, interacting constraints, and emergence of behaviors from multiple subsystems are key concepts of the framework, which are dependent on the individual, task, or environment, and interact to form behaviors like perception, emotion, and action - thus these constraints originate behaviors related to health and well-being. Natural environments are richer for interacting, because there is a variety in surfaces and textures, the temperature changes, sometimes it is raining, and these dynamic features draw rich psychological responses from individuals. On the other hand, indoor environments are more controlled and motionless, and consequently not so prone to elicit affordances for health and well-being (Davids, Araújo, & Brymer, 2016; Yeh, et al., 2015; Brymer, Davids, & Mallabon, 2014).

Although results are promising, analyses were made with a limited number of studies, and should be interpreted with caution. Nonetheless, the evidence found here may help consolidate the outdoor natural environment as the place to exercise in. If these results are further confirmed by future research, exercise and health professionals, urban designers, and policy makers should consider adding more green settings to urban centers, in order to improve mental well-being of populations, and drive behavior change by increasing level of physical activity (Astell-Burt, Feng, & Kolt, 2013; Astell-Burt, Feng, & Kolt, 2014).

References

Akers, A., Barton, J., Cossey, R., Gainsford, P., Griffin, M., & Micklewright, D. (2012). Visual Color Perception in Green Exercise: Positive Effects on Mood and Perceived Exertion. *Environmental Science & Technology*, 46 (16) : 8661-8666.

Akpinar, A. (2016). How is Quality of Urban Green Spaces Associated With Physical Activity and Health? *Urban Forestry & Urban Greening*, 16 : 76–83.

Anson, G., Elliott, D., & Davids, K. (2005). Information Processing and Constraints-Based Views of Skill Acquisition: Divergent or Complementary? *Motor Control*, 9 : 217-241.

Araújo, D. (2009). Ecological Approaches to Cognition and Action in Sport and Exercise: Ask Not Only What You Do, But Where You Do It. *International Journal of Sport Psychology*, 40 : 5-37.

Astell-Burt, T., Feng, X., & Kolt, G. (2013). Mental Health Benefits of Neighbourhood Green Space are Stronger Among Physically Active Adults in Middle-to-Older Age: Evidence From 260,061 Australians. *Preventive Medicine*, 57 (5) : 601-606.

Astell-Burt, T., Feng, X., & Kolt, G. (2014). Green Space is Associated With Walking and Moderate-to-Vigorous Physical Activity (MVPA) in Middle-to-Older-Aged Adults: Findings From 203 883 Australians in the 45 and Up Study. *British Journal of Sports Medicine*, 48 (5) : 404-406.

Barton, J., & Pretty, J. (2010). What is the Best Dose of Nature and Green Exercise for Improving Mental Health? A Multi-Study Analysis. *Environmental Science & Technology*, 44 (10) : 3947–3955.

Beery, T., Jonsson, K. I., & Elmberg, J. (2015). From Environmental Connectedness to Sustainable Futures: Topophilia and Human Affiliation with Nature. *Sustainability*, 7 (7) : 8837-8854.

Bergman, M., Jonides, J., & Kaplan, S. (2008). The Cognitive Benefits Of Interacting With Nature. *Psychological Science*, 19 (12) : 1207-1212.

Bjørgen, K. (2016). Physical Activity in Light of Affordances in Outdoor Environments: Qualitative Observation Studies of 3–5 Years Olds in Kindergarten. *Springerplus*, 5(1): 950.

Borg, G. (1990). Psychophysical Scaling With Applications in Physical Work and the Perception of Exertion. *Scandinavian Journal of Work, Environment & Health*, 16 (1) : 55-58.

Bowler, D. E., Knight, T. M., Pullin, A. S., & Buyung-Ali, L. M. (2010). A Systematic Review of Evidence for the Added Benefits to Health of Exposure to Natural Environments. *BMC Public Health*, 10 (1) : 456.

Brown, D. K., Barton, J. L., Pretty, J., & Gladwell, V. F. (2014). Walks4Work: Assessing the Role of the Natural Environment in a Workplace Physical Activity Intervention. *Scandinavian Journal of Work, Environment & Health*, 40 (4) : 390-399.

Brymer, E., Davids, K., & Mallabon, E. (2014). Understanding the Psychological Health and Well-Being Benefits of Physical Activity in Nature: An Ecological Dynamics Analysis. *Journal of Ecopsychology*, 6 (3).

Calogiuri, G., Evensen, K., Weydahl, A., Andersson, K., Patil, G., Ihlebaek, C., & Raanaas, R. K. (2014). Green Exercise as a Workplace Intervention to Reduce Job Stress. Results From a Pilot Study. *Work*, 53 : 99–111.

Calogiuri, G., Nordtug, H., & Weydahl, A. (2015). The Potential of Using Exercise in Nature as an Intervention to Enhance Exercise Behavior: Results from a Pilot Study. *Perceptual & Motor Skills: Exercise & Sport*, 121 (2) 1-21.

Calogiuri, G., Weydahl, A., Mikkilä, S., Nordtug, H., Horgen, K., Raanaas, R., . . . Ihlebæk, C. (2015). Trening Ute Eller Inne? Rapport Fra et Prosjekt Med Datainnsamling Under Forskningsdagene 2012. *Septentrio Reports*, 2.

Coon, J. T., Boddy, K., Stein, K., Whear, R., Barton, J., & Depledge, M. H. (2011). Does Participating in Physical Activity in Outdoor Natural Environments Have a Greater Effect on Physical and Mental Wellbeing than Physical Activity Indoors? A Systematic Review. *Environmental Science & Technology*, 45 (5) : 1761-1772.

Costall, A. (1984). Are Theories of Perception Necessary? A Review of Gibson's The Ecological Approach to Visual Perception. *Journal of the Experimental Analysis of Behavior*, 41 : 109-115.

Davids, K., Araújo, D., & Brymer, E. (2016). Designing Affordances for Health-Enhancing Physical Activity and Exercise in Sedentary Individuals. *Sports Medicine*, 46 (7) : 933-938.

Dravigne, A., Waliczek, T. M., Lineberger, R. D., & Zajicek, J. M. (2008). The Effect of Live Plants and Window Views of Green Spaces on Employee Perceptions of Job Satisfaction. *Hortscience*, 43 (1) : 183–187.

Ekkekakis, P., Parfitt, G., & Petruzzello, S. (2011). The Pleasure and Displeasure People Feel When They Exercise at Different Intensities. *Sports Medicine*, 41 : 641–71.

Elkington, T. J., Cassar, S., Nelson, A. R., & Levinger, I. (2017). Psychological Responses to Acute Aerobic, Resistance, or Combined Exercise in Healthy and Overweight Individuals: A Systematic Review. *Clinical Medicine Insights: Cardiology*, 11 : 1–23.

Focht, B. C. (2009). Brief Walks in Outdoor and Laboratory Environments. *Research Quarterly for Exercise and Sport*, 80 (3) : 611-620.

Garber, C., Blissmer, B., Deschenes, M., Franklin, B., Lamonte, M., Lee, I., . . . Swain, D. (2011). Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise. *Medicine & Science in Sports & Exercise*, 43 (7) : 1334-1359.

Gibson, J. (1979). *The Ecological Approach to Visual Perception.* Hillsdale: Lawrence Erlbaum Associates.

Hardy, C. J., & Rejeski, W. J. (1989). Not What, but How One Feels: The Measurement of Affect during Exercise. *Journal of Sport & Exercise Psychology*, 11 (3) : 304-317.

Horiuchi, M., Endo, J., Takayama, N., Murase, K., Nishiyama, M., Saito, H., & Fujiwara, A. (2014). Impact of Viewing vs. Not Viewing a Real Forest on Physiological and Psychological Responses in the Same Setting. *International Journal of Environmental Research and Public Health*, 11 : 10883-10901.

Hug, S.-M., Hartig, T., Hansmann, R., Seeland, K., & Hornung, R. (2009). Restorative Qualities of Indoor and Outdoor Exercise Settings as Predictors of Exercise Frequency. *Health & Place*, 15 : 971–980.

Hutchinson, J., & Tenenbaum, G. (2007). Attention Focus During Physical Effort: The Mediating Role of Task Intensity. *Psychology of Sport and Exercise*, 8 (2) : 233-245.

Kaplan, R., & Kaplan, S. (1989). *The Experience of Nature: A Psychological Perspective.* University of Michigan: Cambridge University Press.

Kaplan, S. (1995). The Restorative Benefits of Nature: Toward an Integrative Framework. *Journal of Environmental Psychology*, 16 : 169-182.

Krinski, K., Machado, D., Lirani, L., DaSilva, S., Costa, E., Hardcastle, S., & Helsangedy, H. (2017). Let's Walk Outdoors! Self-Paced Walking Outdoors Improves Future Intention to Exercise in Women With Obesity. *Journal of Sport and Exercise Psychology*, 39 (2) : 145-157.

Lacharité-Lemioux, M., Brunelle, J.-P., & Dionne, I. J. (2014). Adherence to Exercise and Affective Responses: Comparison Between Outdoor and Indoor Training. *NAMS Menopause*, 22 (7) : 731-740.

Lempp, T., de Lange, D., Radeloff, D., & Bachmann, C. (2012). The Clinical Examination of Children, Adolescents and Their Families. In IACAPAP, *IACAPAP e-Textbook of Child and Adolescent Mental Health* (pp. 3-4). Geneva: International Association for Child and Adolescent Psychiatry and Allied Professions: Rey JM.

Mackay, G., & Neill, J. (2010). The Effect of “Green Exercise” on State Anxiety and the Role of Exercise Duration, Intensity, and Greenness: A Quasi-Experimental Study. *Psychology of Sport and Exercise*, 11 : 238-245.

Marselle, M. R., Irvine, K. N., & Warber, S. L. (2013). Walking for Well-Being: Are Group Walks in Certain Types of Natural Environments Better for Well-Being than Group Walks in Urban Environments? *International Journal of Environmental Research and Public Health*, 10 : 5603-5628.

McMurray, R. G., Berry, M. J., Vann, R. T., Hardy, C. J., & Sheps, D. S. (1988). The Effect of Running in an Outdoor Environment on Plasma Beta Endorphins. *Annals of Sports Medicine*, 3 (4) : 230–233.

Plante, T. G., Gores, C., Brecht, C., Carrow, J., Imbs, A., & Willemsen, E. (2007). Does Exercise Environment Enhance the Psychological Benefits of Exercise for Women? *International Journal of Stress Management*, 14 (1) : 88–98.

Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The Mental and Physical Health Outcomes of Green Exercise. *International Journal of Environmental Health Research*, 15 (5) : 319-337.

Rietveld, E., & Kiverstein, J. (2014). A Rich Landscape of Affordances. *Ecological Psychology*, 26 : 325–352.

Rogerson, M., & Barton, J. (2015). Effects of the Visual Exercise Environments on Cognitive Directed Attention, Energy Expenditure and Perceived Exertion. *International Journal of Environmental Research and Public Health*, 12 (7) : 7321-7336.

Rogerson, M., Brown, D. K., Sandercock, G., Wooller, J.-J., & Barton, J. (2016). A Comparison of Four Typical Green Exercise Environments and Prediction of Psychological Health Outcomes. *Perspectives in Public Health*, 136 (3) : 171-180.

Rogerson, M., Gladwell, V. F., Gallagher, D. J., & Barton, J. L. (2016). Influences of Green Outdoors versus Indoors Environmental Settings on Psychological and Social Outcomes of Controlled Exercise. *International Journal of Environmental Research and Public Health*, 13 (4) : 363.

Seifert, L., & Davids, K. (2015). Ecological Dynamics: a Theoretical Framework for Understanding Sport Performance, Physical Education and Physical Activity. *CS-DC'15 World E-Conference.* Tempe, United States.

Shanahan, D. F., Franco, L., Lin, B. B., Gaston, K. J., & Fuller, R. A. (2016). The Benefits of Natural Environments for Physical Activity. *Sports Medicine*, 46 (7) : 989-995.

Shepherd, S. O., Wilson, O. J., Taylor, A. S., Thogersen-Ntoumani, C., Adlan, A. M., Wagenmakers, A. J., & Shaw, C. S. (2015). Low-Volume High-Intensity Interval Training in a Gym Setting Improves Cardio-Metabolic and Psychological Health. *PLoS One*, 10 (9) : e0139056.

Shin, Y.-K., Kim, D. J., Kyunghee, J.-C., Son, Y.-j., Koo, J.-W., Min, J.-A., & Chae, J.-H. (2013). Differences of Psychological Effects Between Meditative and Athletic Walking in a Forest and Gymnasium. *Scandinavian Journal of Forest Research*, 28 (1) : 64-72.

Svebak, S., & Murgatroyd, S. (1985). Metamotivational Dominance: A Multimethod Validation of Reversal Theory Constructs. *Journal of Personality and Social Psychology*, 48(1) : 107-116.

Taylor, L., & Hochuli, D. (2017). Defining Greenspace: Multiple Uses Across Multiple Disciplines. *Landscape and Urban Planning*, 158 : 25–38.

Thayer, R. E. (1986). Activation-Deactivation Adjective Check List: Current Overview and Structural Analysis. *Psychological Reports*, 58 (2) : 607-614.

The Prisma Group, Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine*, 6 (7) : e1000097.

Triquero-Mas, M., Dadvand, P., Cirach, M., Martinez, D., Medina, A., Mompart, A., . . . Nieuwenhuijsen, M. J. (2015). Natural Outdoor Environments and Mental and Physical health: Relationships and Mechanisms. *Environment international*, 77 : 35-41.

Tuan, Y. (1974). *Topophilia: A Study of Environmental Perception, Attitudes, and Values.* New York, USA: Prentice-Hall: Englewood Cliffs.

Turner, T. L., & Stevinson, C. (2017). Affective Outcomes During and After High-Intensity Exercise in Outdoor Green and Indoor Gym Settings. *International Journal of Environmental Health Research*, 27 (2) : 106-116.

Ulrich, R. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman, & J. Wohlwill, *Human Behavior and Environment, Vo1.6: Behavior and Natural Environment* (pp. 85-125). New York: I. Altman & J. Wohlwill.

Ulrich, R., Simons, R., Losito, B., Fiorito, E., Miles, M., & Zelson, M. (1991). Stress Recovery During Exposure to Natural and Urban Environments. *Journal of Environmental Psychology*, 11 : 201-230.

White, M. P., Pahl, S., Ashbullby, K. J., Burton, F., & Depledge, M. H. (2015). The Effects of Exercising in Different Natural Environments on Psycho-Physiological Outcomes in Post-Menopausal Women: A Simulation Study. *International Journal of Environmental Research and Public Health*, 12 (9) : 11929-11953.

Williams, A. L. (2011). *Perceived Environmental Restorativeness and Affective Responses to Indoor vs. Outdoor Exercise.*

Wilson, E. O. (1984). *Biophilia.* Harvard: Harvard University Press.

Withagen, R., & Caljouw, S. R. (2015). ‘The End of Sitting’: An Empirical Study on Working in an Office of the Future. *Sports Medicine*, 46 (7) : 1019-1027.

Yeh, H., Stone, J., Churchill, S., Brymer, E., & Davids, K. (2016). Designing Physical Activity Environments to Enhance Physical and Psychological Effects. *Procedia Engineering*, 147 : 793-798.

Yeh, H., Stone, J., Churchill, S., Wheat, J., Brymer, E., & Davids, K. (2015). Physical, Psychological and Emotional Benefits of Green Physical Activity: An Ecological Dynamics Perspective. *Sports Medicine*, 46 (7) : 947-953.